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ELECTROMECHANICAL

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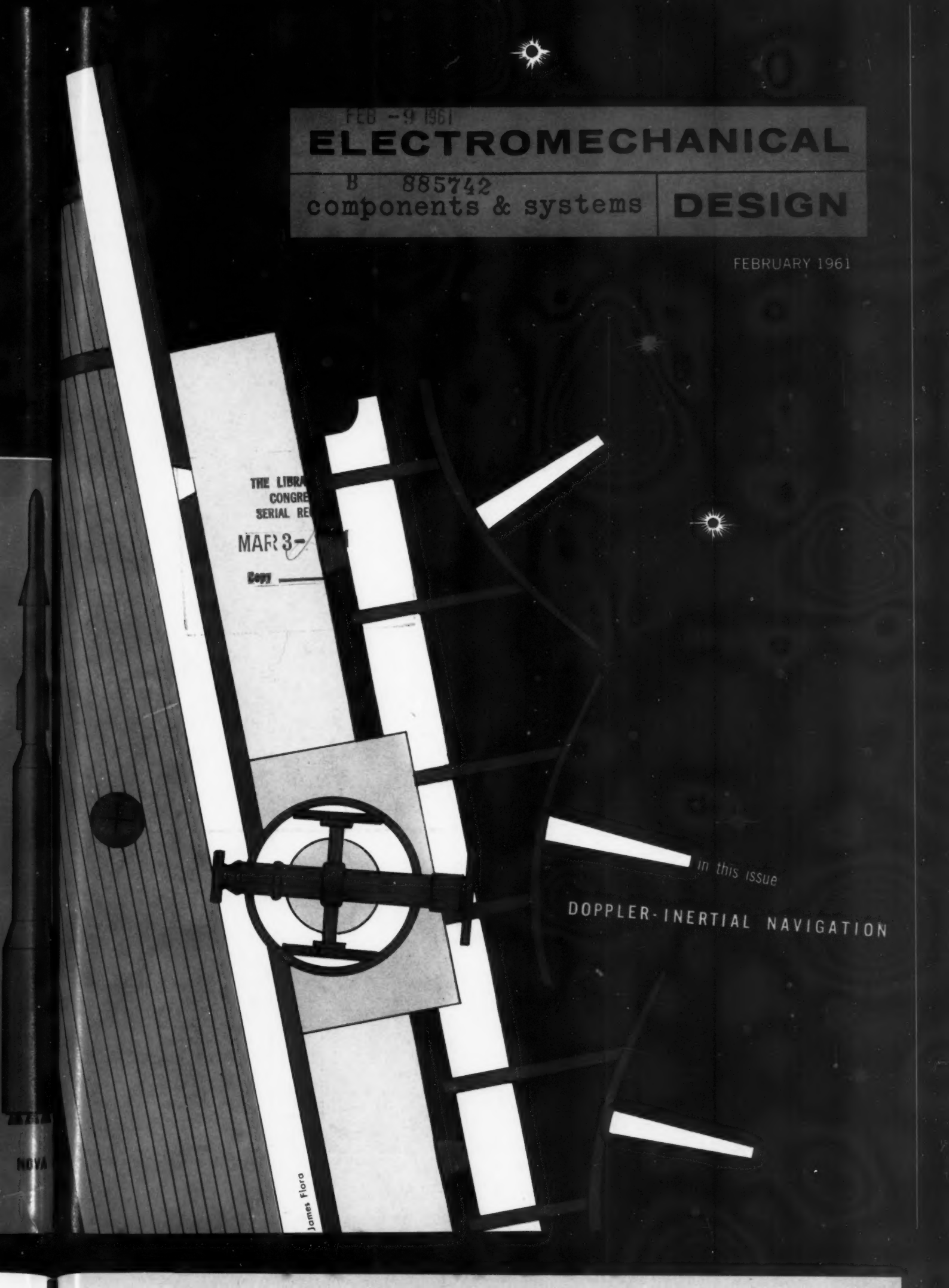
components & systems DESIGN

FEBRUARY 1961



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James Flora

in this issue

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NUMBER 5—RELIABILITY SERIES

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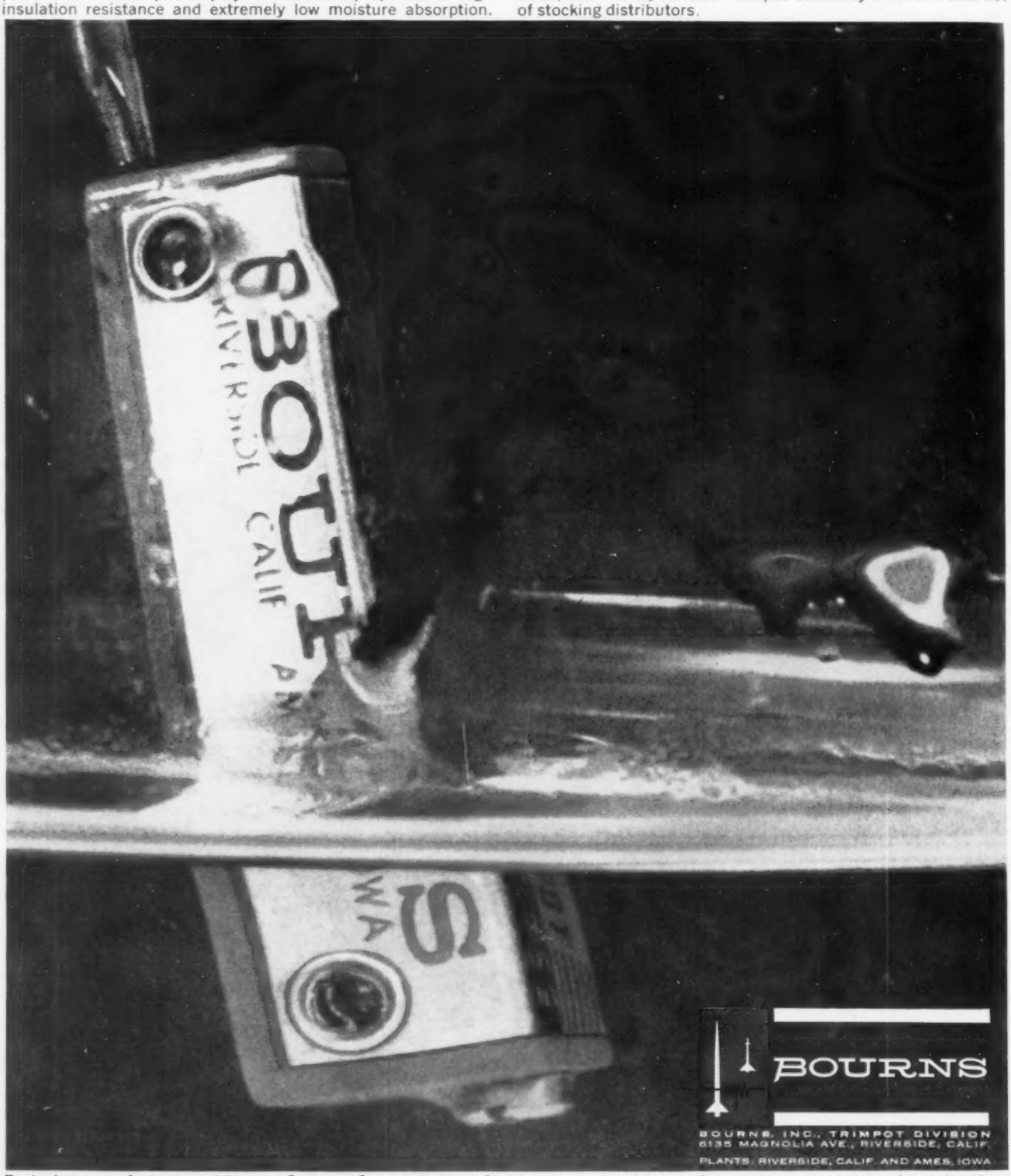

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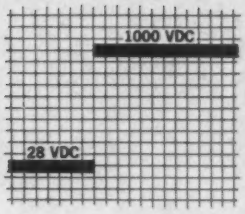

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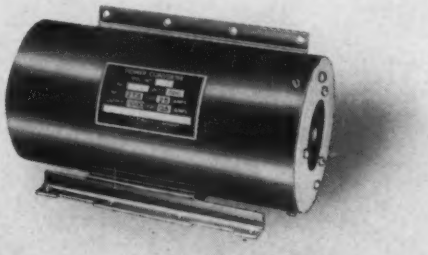

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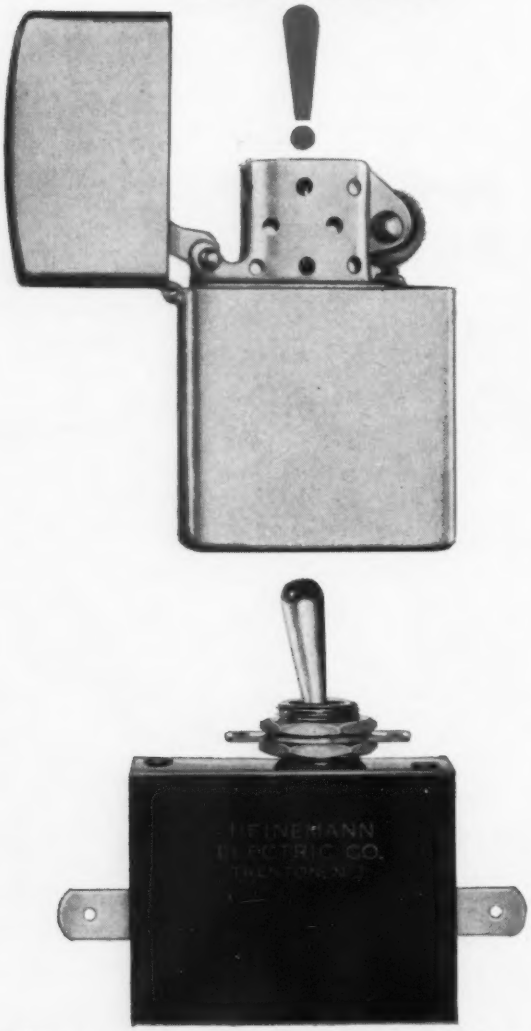

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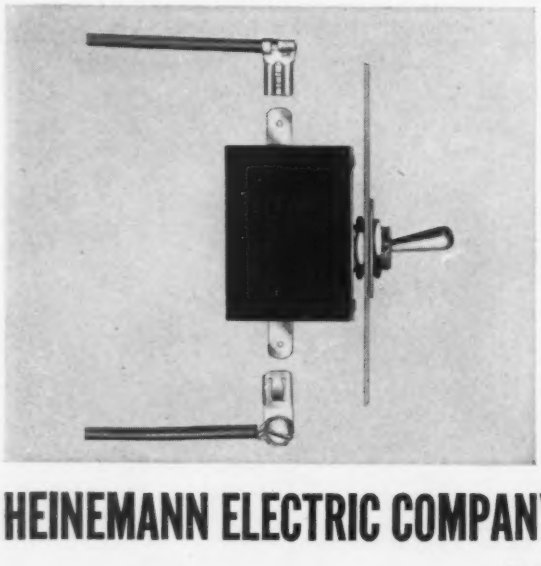

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CIRCLE NO. 2 ON INQUIRY CARD

ELECTROMECHANICAL components & systems DESIGN

The Sourcebook of Design Ideas in Applied Electromechanics

FEBRUARY 1961 • VOL. 5 NO. 2

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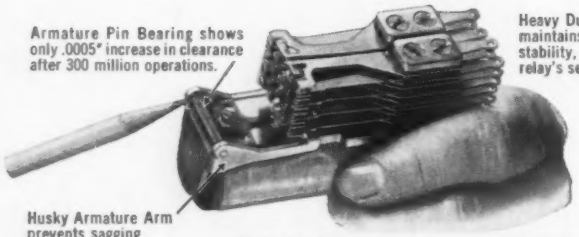
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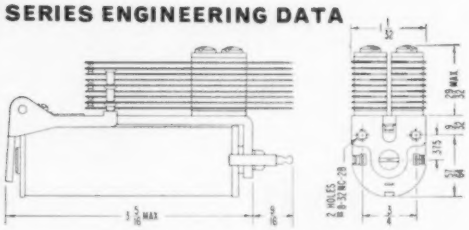

GENERAL:
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- **Material:** ⅛" dia. twin palladium. Up to ¼" dia. single silver. Other materials on special order.
- **Lead:** 4 amps at 115 volts, 60 cycle resistive
- **Pressure:** 15 grams minimum

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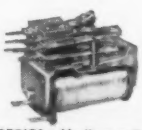

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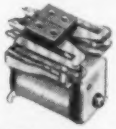

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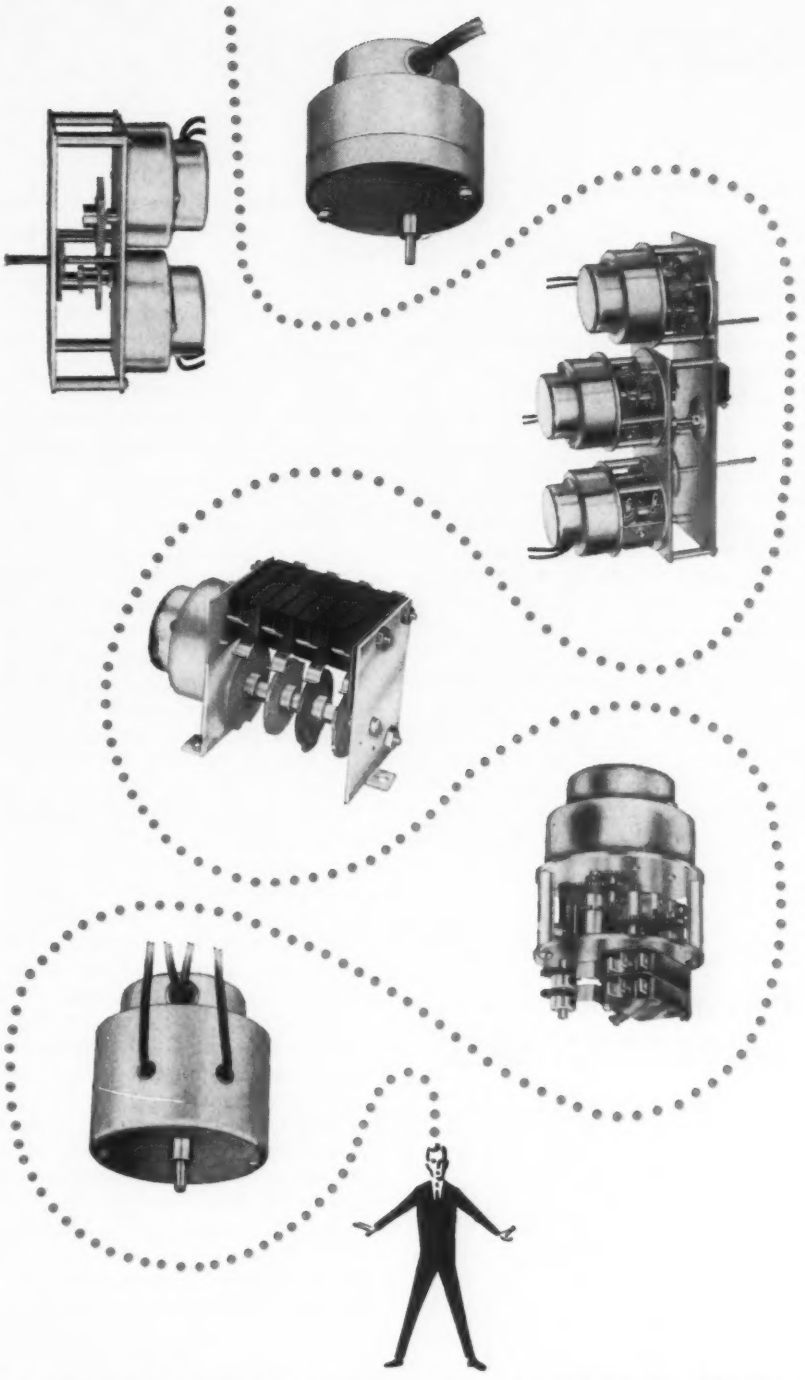

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CIRCLE NO. 4 ON INQUIRY CARD

Seismic System Semantics

An article by Mr. E. F. Kiernan appeared in the October, 1960 Electro-Mechanical Design. This article was an interesting and informative description of various aspects of seismic systems. Unfortunately, there were several errors in that article which I would like to call to your attention. Mr. Kiernan defines natural frequency as "that frequency at which a device or system would tend to oscillate, if the damping were reduced to zero." This definition coincides with the accepted definition that he natural frequency is that frequency at which the phase lag between a sinusoidal input acceleration and the motion of the seismic mass is 90°. He then states that natural resonance occurs when "the frequency of the source is the same as the natural frequency of the driven system." This, however, is only true when the damping is zero. The frequency at which natural resonance occurs (the frequency at which an underdamped free system will oscillate after a disturbance) is determined as follows:

$$f_r = f_n(1-H^2)\,½$$

Where: f_r = natural resonance frequency
f_n = natural frequency
H = damping ratio

This frequency moves towards zero as the damping approaches critical (an over-damped system will, of course, have no natural resonance). I feel that this discrepency can be misleading in discussion considering seismic systems.

Mr. Kiernan's definition of damping is also slightly misleading. He defines damping as "the forces acting on an oscillatory system to reduce the amplitude of oscillation." Although this is true for under-damped systems, the definition should be worked to include any system whether over-damped or underdamped.

Later in the article, Mr. Kiernan discusses amplitude resonance and notes that "as the damping is increased, the peak amplitude occurs at lower and lower frequencies." He continues "with heavy damping no peak is in evidence." I feel it is pertinent to mention that the transition occurs at a damping of 0.707 times critical. At this damping, the frequency at which the amplitude resonance occurs approaches zero and the peak disappears.

I feel that this article, with these corrections, provides a good, practical discussion of seismic systems. If my comments above are incorrect, I would appreciate hearing from Mr. Kiernan.

W. J. Barmore
Chief Engineer Instruments
Genisco, Inc.

Here's Mr. Kiernan's answer:

I consider Mr. Barmore's comments to be excellent examples of how easy it is to misinterpret the classical theory regarding motion in a damped seismic system.

Referring to my definition of natural frequency Mr. Barmore states, quote "This definition coincides with the accepted definition that the natural frequency is that frequency at which the phas lag between a sinusodial input acceleration and the motion of the seismic mass is 90°", unquote. The word 'motion' which Mr. Barmore uses is a generic term having three components, i.e. displacement, velocity, and acceleration. The statement in the quote is also unclear as to which component is lagging. Assuming Mr. Barmore means 'displacement' when he uses 'motion', let's have a look at Fig 3b, in my article. . . . At first glance the acceleration of the driving force is lagging 90° behind the displacement of the driven system. However, to so state, places the cart before the horse, the driving force is the cause and the motion of the driven system is the effect. It would be better to say that the displacement of the seismic system lags the driving force displacement by 90°. Even more pertinent, in some instances, is the fact that the velocity of the driving force and the acceleration of the driven system are in phase, as is also shown in Fig 3b and is discussed in the article.

Mr. Barmore next discusses natural resonance, quote, "He then states that natural resonance occurs when 'the frequency of the source is the same as the natural frequency of the driven system'. This, however, is only true when the damping is zero." unquote. If Mr. Barmore had taken a good look at Fig 4, in the article . . . he would have observed that the driving force frequency coincides with the natural frequency at a fixed value regardless of the damping. The fixed value is determined by th eeffective mass and spring constant of the driven system; mathematically

$$f_n = (k/m)\,½$$

where k is the spring constant and m is the mass. Incidentally, the curves shown in Fg 4 are smular to those found throughout the literature and did not originate with me. In fact, with the exception of Fig 3a,b,c, this holds for the rest of the figures.

With regard to damping . . . I concur with the next to last paragraph of Mr. Barmore's comments, especially the last sentence. Too frequently one reads a statement to the effect that in over-damped systems the peak moves toward zero frequency and reaches a maximum at that point.

In conclusion I would like to point out that many of the differences in opinion stem from semantic variations, i.e. using the same words to express different meanings. As can be noted, I prefixed my discussion in the article with a set of definitions.

Anyone interested in the viewpoint of another writer on this subject should read issues number 2 and 12 of Statham Laboratorie's Instrument Notes.

E. F. Kiernan
835 S. Westgate Ave.
Los Angeles 49, Calif.

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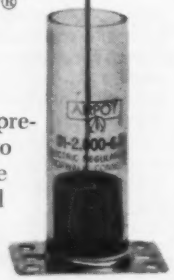

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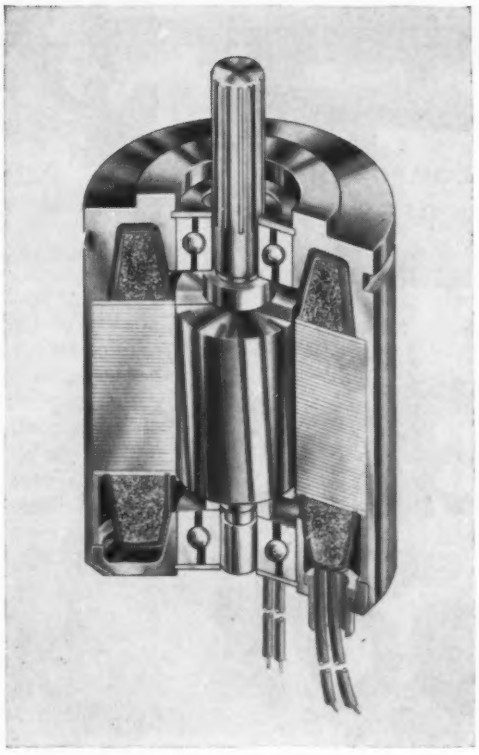

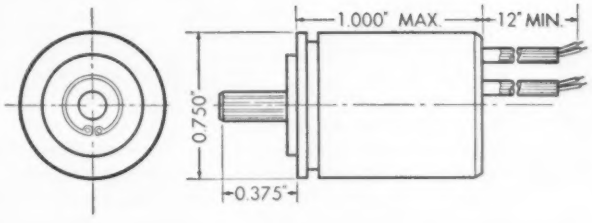

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Type Number	008E2A	008E2C	008E2D
Excitation Frequency (cps)	400	400	400
Rated Voltage:			
Fixed phase (volts)	26	26	26
Control phase (volts)	26	40/20	26
Input Power at Stall (watts)	1.75	1.75	2.50
Starting Voltage (volts)	0.68	1.0	0.68
Stall Torque (oz. -in.)	0.22	0.22	0.30
Ratio Stall Torque to Total Power Input	0.060	0.060	0.060
Rotor Inertia (gm. cm^2)	.414	.414	.414
Acceleration at Stall (rad./$sec.^2$)	36,000	36,000	53,000
No Load Speed (rpm)	6,500	6,500	6,500
Temperature Rise at Stall (°C)	50	50	60
Operating Temperature Range (°C)	−55 to +125	−55 to +125	−55 to +125

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CONTRACTS

Studies of high-temperature air may ultimately result in overcoming the communications "blackout" caused by radio waves' incapacity to penetrate the ionized, hot gases surrounding re-entering space vehicles and satellites. A year-long investigation into the fundamental nature and characteristics of the interaction between electromagnetic waves and air at temperatures from 9,000 to 25,000°F will be undertaken by the Avco-Everett Research Laboratory. The contract, awarded by the Air Force Research Cambridge Laboratories, AFRD, totals $289,330. It includes theoretical and experimental studies of radiation properties, heat and electrical conductivity, and other properties of air in both equilibrium and non-equilibrium conditions.

Nine additional long-range radars for the Federal Aviation Agency's nationwide air-traffic control network will be produced and installed by the Raytheon Co. under a 5.2 million dollar contract. Through a device which applies spin to the radar waves, radars will detect and track aircraft during inclement weather which frequently causes excessive "clutter." Raytheon calls this spin circular polarization. Circular polarized microwaves rebound from spherical raindrops to the antenna with a reverse "twist" and are blocked from entering the receiver by an electronic filter. Microwaves striking irregular surfaces of solid objects, on the other hand, rebound with the original "twist", thus passing unhindered through the filter to register on the scope.

A gyro platform that will furnish precise reference data to the Strategic Air Command's new B-70 intercontinental bomber will be developed and manufactured by the Sperry Gyroscope Co., Great Neck, N.Y. under a U. S. Air Force contract. The twin-gyro platform consists of highly accurate accelerometers and gyroscopes that will provide attitude and heading reference in any weather, day or night, and at any point on the Earth. The lightweight platform, a new form of basic flight reference, employs two identical directional gyros set at right angles to each other to create a "table" which will remain stable in space despite any maneuvering of the aircraft.

BRIEFLY:

Fire control systems: $34 million to the General Electric Ordance Dept. from the U. S. Navy.

Capacitors: $1,700,596 to Sprague Electric Co., North Adams, Mass. from North American Aviation, Autonetics Div.

Missile control radar: $8.3 million to Westinghouse from U. S. Navy.

Analog-to-digital converters: $435,000 to Gulton Industries, Albuquerque, New Mexico for the Sergeant Missile Program.

Silver-zinc batteries: $487,089 to Telecomputing Corp., Cook Batteries Div. from North American Aviation, Autonetics Div.

Electronic test equipment: Over $3 million to Fairchild Camera and Instrument Corp., Clifton, New Jersey from IBM.

Gyro systems: $370,000 to Giannini Controls Corp., Duarte, Calif. from the Martin Co.

Power supply instrumentation: $61,000 to Computer Engineering Assoc., Pasadena, Calif. from Convair.

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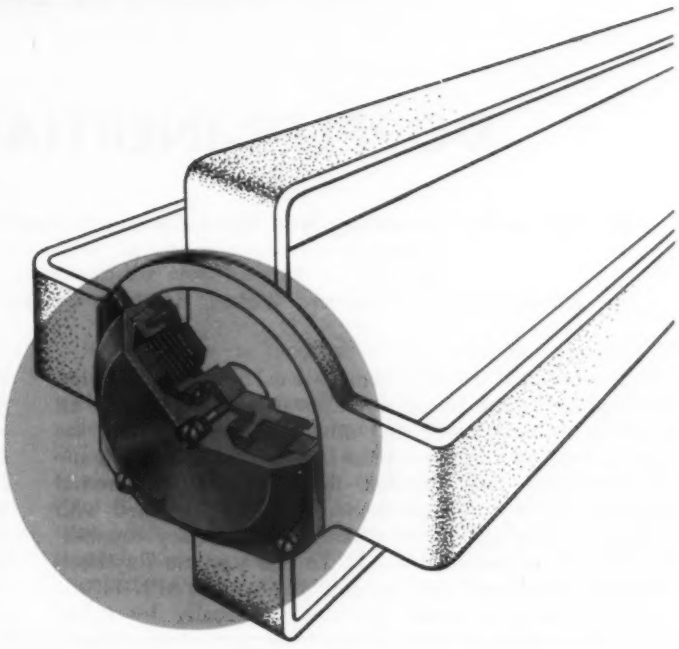

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Amps at peak torque	1.6	2.0	1.3
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Rotor Inertia, oz. in. sec^2	.007	.007	.007
Weight, oz.	9	9	9
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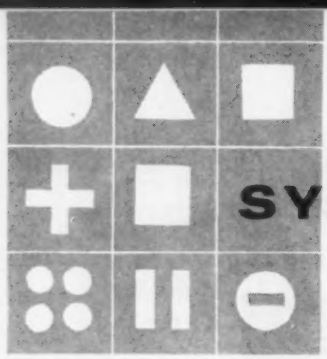

SYSTEMS DESIGN

DOPPLER-INERTIAL NAVIGATION

Ground Facility Simulating Free Space Boresights Antenna Clusters to Within 0.01 Degree Angular Error

Stanley Kahn and Bernard Waters, Raytheon Company, Equipment Division, Sudbury, Massachusetts

When the B-58 Hustler bomber was in its early design stages, both the Air Force and Convair recognized that an aircraft with such speed and other advanced features required a navigation system of the highest attainable accuracy and reliability. They decided, therefore, that the inertial navigation system to be used should be supplemented with a Doppler radar navigation system with accuracy capabilities theretofore never achieved. To this purpose Raytheon Company developed the Doppler Radar AN/APN-113.

Aircraft Doppler radar operates principally by transmitting three separate radar beams from one antenna cluster and receiving reflections of these beams from the earth (or sea) on another 3-antenna cluster. Information available from the reflections is resolved into coordinates of forward, transverse and vertical velocity. This information is then fed into a navigation computer where it is transformed into latitude and longitudinal coordinate display, or used to operate the aircraft flight controls directly to bring it to a desired destination.

Accuracy of a Doppler navigation system is limited by many factors, one of the most important being the accuracy with which the transmitting and receiving antennas can be aligned in their prescribed directions with respect to each other and to the aircraft. The standard method of calibrating equipment of this type is to mount the antenna assemblies in an aircraft without precision alignment, fly them over a calibrated course, and compare the Doppler radar navigator output with actual flight path data gathered. After repeated flight tests, the actual error is compensated by calibration adjustments. Using this method, an accuracy of about 1% has been achieved; but the method has several drawbacks, including lack of interchangeability between antenna assemblies and aircraft. When parts are replaced, the system may require additional flight tests and recalibration. This method has been found to be time-consuming, too expensive and insufficiently accurate, without an excessive number of flights under different conditions, to be applicable for the high accuracy AN/APN-113 system.

During development of Raytheon's Doppler radar, photogrammetric techniques were used to evaluate system accuracy. Photographs taken at a given altitude over a measured and marked course at precise intervals during flight tests were compared with the doppler radar velocity measurements which had been passed thru special computers and recorded on magnetic tape. The data then had to be reduced after the flight test. This process was also considered too costly and time-consuming for production purposes.

When Raytheon undertook the program the specifications called for a navigation accuracy of 0.1% which was considerably tighter than had been previously achieved. Allowing for permissable errors in the electronic and microwave equipment, analysis determined that the maximum allowable error in the direction of one antenna beam with respect to the others was 0.01 degree. This represents a displacement of 0.21 inch at 100 feet distance.

Raytheon decided therefore to align the antennas in a ground facility. They have termed this process boresighting. It required the transmitter and receiver antenna clusters to be accurately aligned with respect to each other and to a set of mounting supports which would be used to position them when installed in the aircraft. The aircraft would, in turn, provide the mating supports, previously aligned to receive the antenna clusters, thus providing interchangeability. The boresighting operation was to consist of mounting the antenna cluster assembly on a support pedestal, fastening it with a mounting and alignment system identical to that used in the aircraft and operating it as a transmitter in one end of an absorbent tunnel. The signal would be received by an array of horns spaced along both the horizontal and vertical axes of a receiver stand at the other end of the tunnel, a distance of 100 ft. Orientations of both the transmitter and receiver pedestals were to be controllable in azimuth and elevation. The transmitted signal would be compared in horn pairs for amplitude and phase differences, and the orientation of both stands would be adjusted until the signal differences were nulled out. Optical equipment would be used to measure the stand rotation angles against a reference and the antennas repositioned until their beams came within the allowable tolerance of the specified angles.

Because of the great distance between the stands precision optical methods for measuring the antenna beam angles were necessary. Several methods were available for measurement of relative angles in space, two of the most common being auto-reflection and auto-collimation. Although auto-collimation is the more accurate of the two its main drawback is the difficulty of viewing this accuracy within a telescope at great distance. Therefore we chose the auto-reflection method for greater clarity, less chance of reading error, and faster use.

The auto-reflection system uses a target ring mounted concentrically on the objective end of a telescope, illumi-

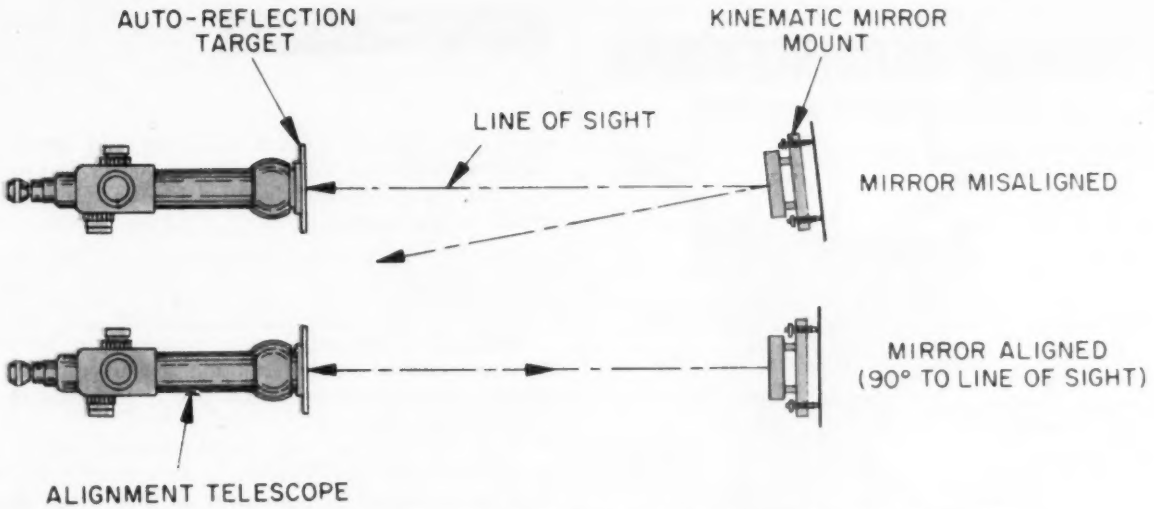

Fig 1 Auto-reflection technique. When the axis of the telescope is exactly 90 degrees to the mirror, the reflected target will align with the cross hairs of the telescope.

nated from in front and from a side, and whose face is roughly parallel to an optically flat mirror approximately in line at some distance away. The reflection of the target will be seen through the telescope, and when the axis of the telescope is exactly 90° to the mirror, the reflected target will align to perfection in both azimuth and elevation with the cross hairs of the telescope. However, if the mirror or the telescope are slightly tilted in any plane the reflected target will not coincide with the crosshairs of the telescope (Fig 1).

If a mirror were mounted on the receiver stand with its optical face parallel with the face of the horns and viewed with a telescope mounted on the transmitter stand, the reflected image could be used to establish a reference or "0" point. By expanding this system to a multiple number of mirrors at proper distances apart, both stands could be rotated and stopped very accurately at predetermined positions when the reflected target showed in the proper mirror through the telescope (Fig 2). By adding an accurate angular reading system to the telescope on the transmitter

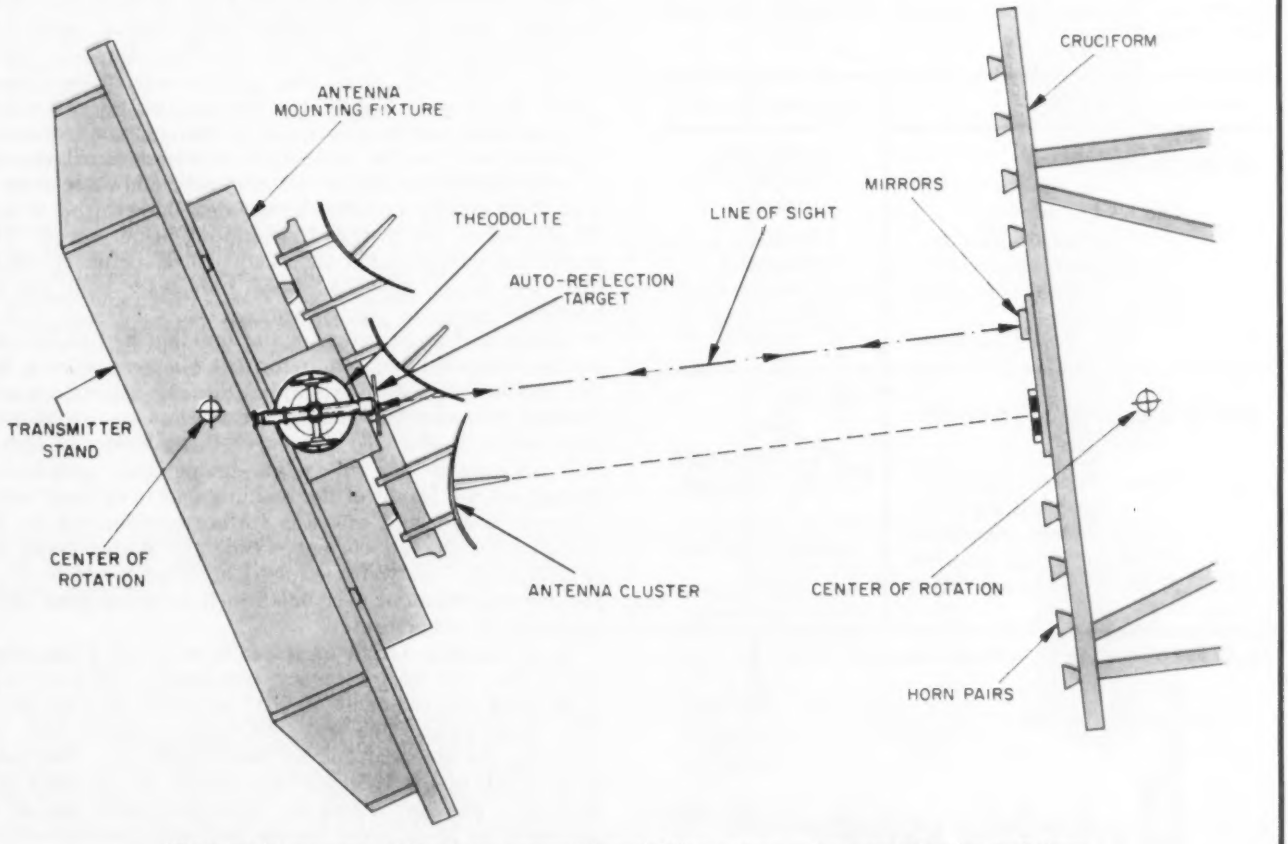

Fig 2 Basic geometry of Raytheon antenna boresighting system using auto-reflection technique.

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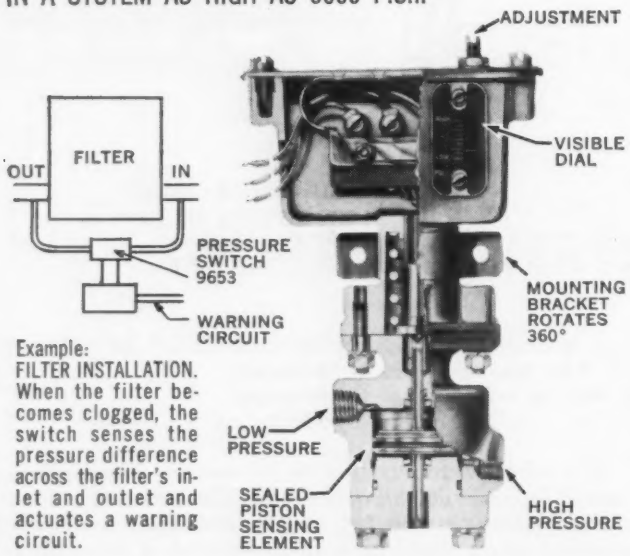

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stand, the angle of rotation could be read directly. With slight modifications to its mounting system, we found that a Wild T-2 Theodolite mounted on the transmitter stand would be the answer.

DESIGN PROBLEMS

Although a ground facility appeared to be the only practical method for boresighting the antennas to the accuracy required, it presented many problems in diverse engineering fields.

- Test antennas and receiving equipment had to be supported on pedestals completely free from vibration and deflections caused by movement of people and equipment within the building and ground vibrations due to vehicles moving outside the building. Settling and shifting of the test stands was specified at a maximum of 0.015 inch per year, resulting from all causes. Stability of the pedestals and associated machinery presented separate problems in themselves. As is generally known, metals possess an "elastic" quality that for most applications is negligible, or by certain engineering principles can be reduced to minute quantities. In some cases, parts are designed to massive proportions to minimize deflections for a given load. In our case, even small deflections were a serious problem. We also recognized that if this stability were to be achieved, temperature variations would have to be minimized. Air conditioning would have to be specified for the building.
- Free space had to be simulated within a building to a degree compatible with the alignment accuracy requirements. Signal reflections from the tunnel walls would add to the directly transmitted signal at the receiver end of the building, forming a composite signal which would be picked up by the receiver horns. The composite signal would vary in both phase and amplitude from the desired direct signal according to the strength of the reflections. The antenna angles, then, would null on the composite signal rather than the directly transmitted signal desired. In order to operate within the maximum allowable error of 0.01°, the reflected energy level would have to be at least 45 db below the directly transmitted beam signal. This requirement represented an isolation level better by 10 db than any tunnel that had been previously built for the frequency range of our system.
- Design and construction of the building had to be compatible with all other requirements. The requirement that the stands be free of vibration due to vehicular traffic dictated that the building be located in an area isolated from heavy traffic. To prevent refraction of the optical and microwave line of sight, temperature distribution throughout the height of the building had to be held within a narrow range, and this was further complicated by the fact that moving air currents inside the tunnel could not be tolerated. The walls required a stiffness which would prevent deflections of over 0.015 inch resulting from vibrations and all other causes.
- Beam angles had to be measured to an order of magnitude better than the final accuracy requirement of 0.01°. To make these measurements, 0.001° accuracy was necessary.
- In some measurable way, reference surfaces, both for mounting the antennas and for later inspection (after numerous flights of the B-58 aircraft) had to be provided in a permanent manner. However, these references had to be adjustable so as to allow inexpensive mass production and assembly. During the boresighting operation, these references had to be accurately defined and made permanent.

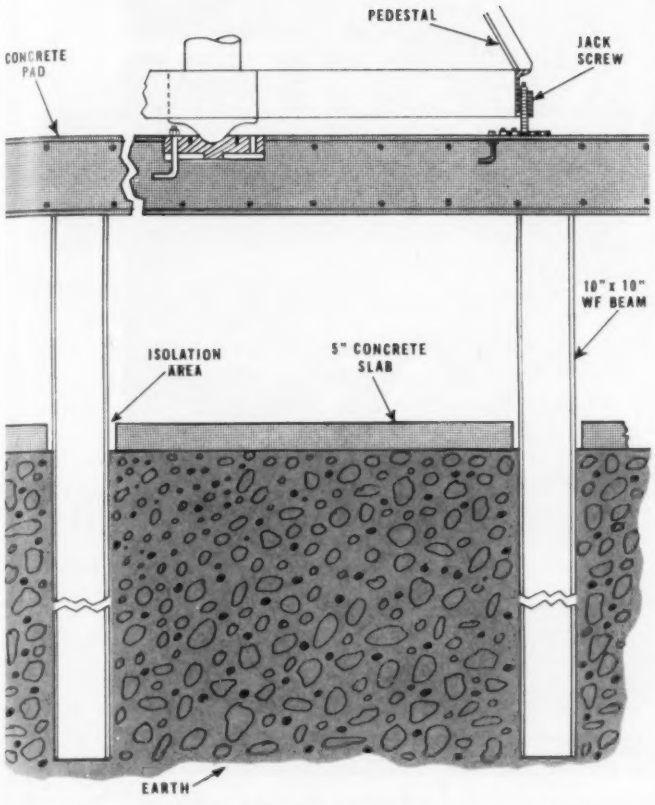

Fig 3 Foundations for the transmitter and receiver stands were built prior to construction of the building and pouring of its foundation. For each stand foundation, four 10 x 10" steel WF beams were driven approximately 50 ft deep into undisturbed earth until they reached "refusal". On top of each set of pillars, a 14 inch thick reinforced concrete platform 18 by 15 ft was poured. Embedded in the concrete were steel mounting pads for support of the stands and associated base machinery. When the concrete floor of the building was poured, a space approximately one inch wide was left around all the sides of the vertical pillars to provide isolation from the building floor. This isolation prevents vibrations and movements of the building due to storms and numerous other environmental causes from entering the pillars and being transmited to the pedestals. Most of the weight (sufficient to stress or preload the exterior extremities of the stand) is borne by three jack screws, whose contact surfaces are also spherical. In addition, very excellent facilities for leveling or "plumbing" the sands are available.

• Mounting surfaces in the B-58 aircraft had to be prepared to receive and accurately position any production antenna assembly.

PEDISTAL DESIGN

Since overall stability of the test equipment was of utmost importance, rigid foundations were required for the transmitter and receiver pedistals and machinery. A concrete pad resting on four vertical pillars driven into the earth was selected as the most effective support for each stand. Fig 3 describes design of the pedistal foundations.

To achieve the specified "boresighting", accuracy, the pedestals had to be completely devoid of lost motion or

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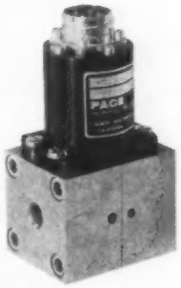

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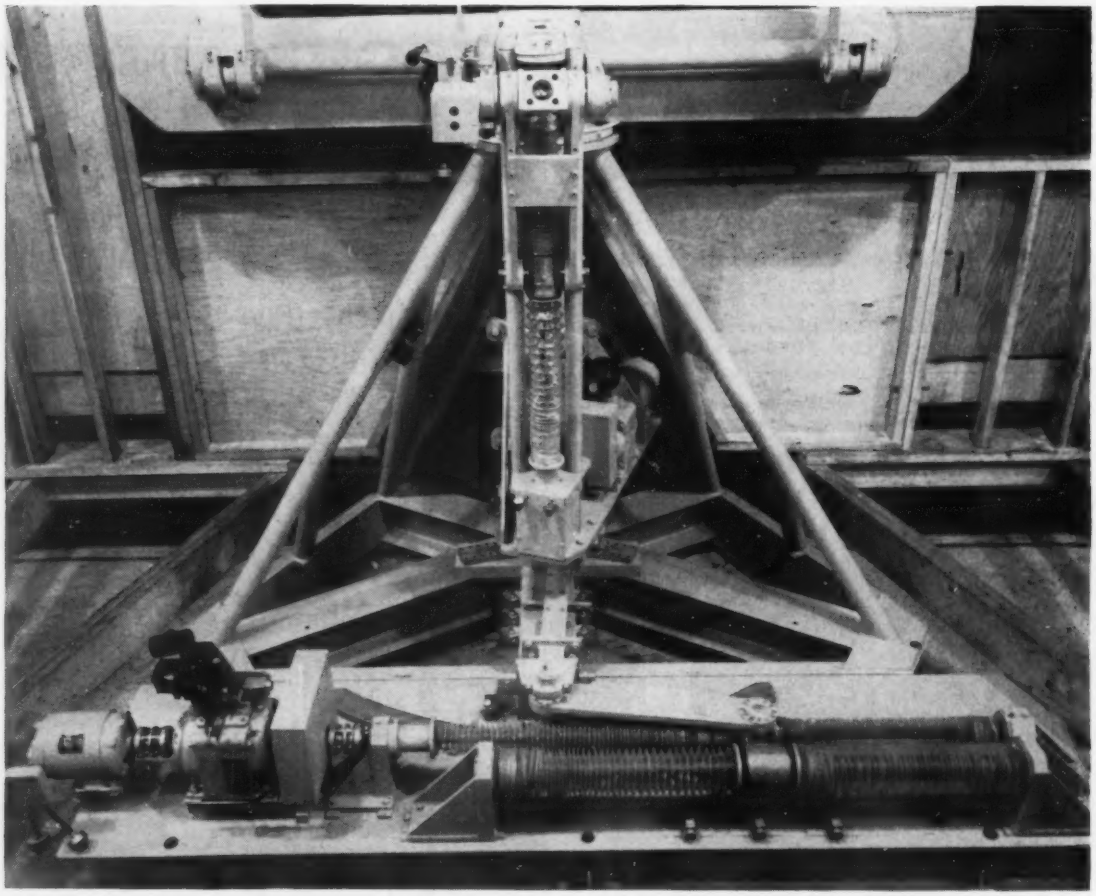


Fig 4 Azimuth drive system. The variable speed motor drives thru a mechanical variable-speed drive whose output shaft is coupled to a Beaver Precision Product's ball-screw and a ball-spline assembly. Between the ball-screw and ball-spline assemblies is a common housing or bridge on which is a pivot shaft. From this pivot shaft, a link-arm connects to the main drive yoke that rotates the entire upper portion of the pedestal in azimuth. The ball screw is hardened and ground steel, with two nuts containing recirculating hardened steel balls, mounted on opposite ends of the common bridge. By fastening one of these nuts to the common bridge and rotating the other until contact is made with the bridge on the opposite end, a preload is applied between the two nuts and the ball screw. After preloading, the second unit is doweled against any radial motion. If after long usage, wear occurs between the nuts and screw, one of the nuts can be preloaded again and redoweled. These techniques insure against lost motion or inaccuracy over the life of the stand. Although both ends of the ball screw are mounted on Timken tapered roller bearings and preloaded so that the ball screw is in tension, it tends to deflect under certain conditions because of its length. A ball spline, which is a stationary hollow tube, imparts stiffness to the ball screw through the common bridge. This ball spline is constructed along the same principles as the ball screw, with recirculating hardened steel balls rolling, in splines or grooves on the surfaces of the tube, from one end of the tube to the other. This tube is also stressed by holding it in tension from both of its threaded mountings on the ends.

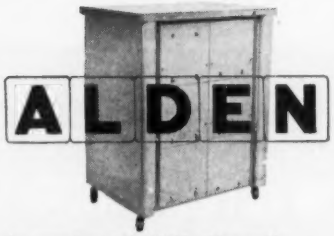
backlash. Use of gears was therefore avoided wherever possible because of the wear that occurs between gear teeth. And wherever gears were used they were designed so that adjustment could be easily made to compensate for wear whenever necessary. The majority of the drive equipment is composed of massive cranks, levers and arms whose connecting or pivot points are rugged shafts and opposed precision Timken tapered roller bearings. At assembly, all of these bearings were preloaded so that all axial and, most important, all radial play were removed. In addition, all pivot points were included in a small sealed cavity that could be filled with light oils for lubrication. Light oils were used to keep friction or drag in the bearings to a minimum.

Another design technique that decreased deflections during test stand operation was to keep all of the heavy parts near the base and adequately supported and to use lightweight aluminum alloys in the upper portions. Since the building was air conditioned, expansion and contraction of dissimilar metals was no problem. We also were very careful to distribute weight over and around pivot points so as to achieve good balance and eliminate or decrease eccentric loading. As a result, deflections from static loading, which was kept low in relation to the mass of the supporting members, are small. Fig 4 describes the azimuth drive system.

TUNNEL AND BUILDING DESIGN

The firm of Emerson & Cuming, Inc. of Canton, Mass. was hired as a consultant to provide the tunnel design and specify the absorbent lining materials to meet the isolation level required. They recommended the shape for the interior of the tunnel illustrated in Fig 5.

The building was designed to fit the shape of the tunnel following the angle of the tapered walls, ceiling and floor. Requirement that the tunnel dimensions be held within a tolerance of ½ inch and that tunnel deflections not exceed 0.015 inch were unique in the building trade, especially in view of the size of the building. They were met by



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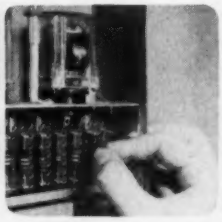

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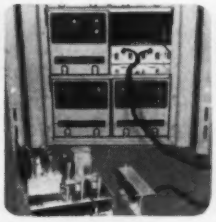

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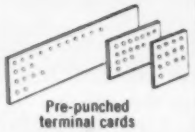

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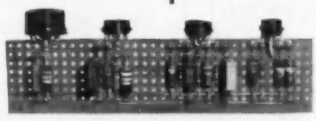

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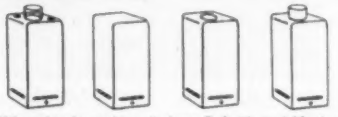

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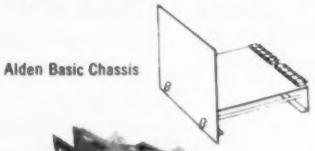

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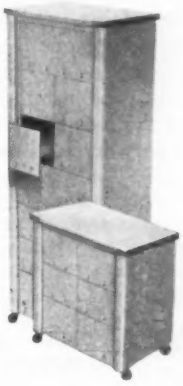

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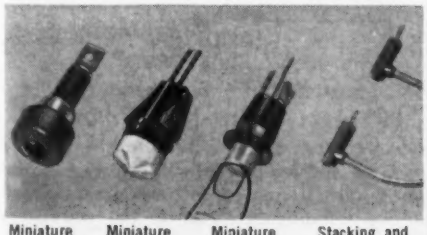

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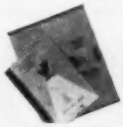

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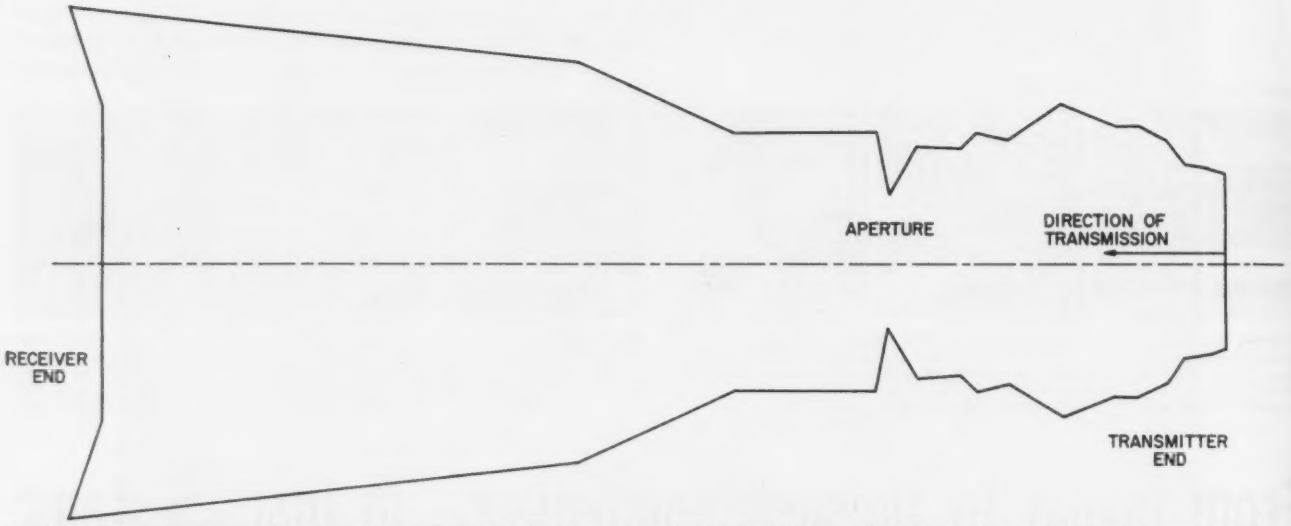

Fig 5 Raytheon's antenna boresighting tunnel, 100 feet long overall, 36 feet high, and 46 feet wide at the receiver end, is characterized by a multiwalled labyrinth trap at the transmitter end, followed by an aperture with critical shape and dimensions that are functions of the transmitted frequency and shape of the radiated beam. Following the aperture, the tunnel surfaces all diverge uniformly toward the receiver end. The labyrinth trap at the transmitter end of the tunnel is designed to cause all the energy radiating from the sides of the antenna to be bounced by successive reflections, each one reducing the power level, before they get through the aperture opening.

designing the walls and roof supports in the form of steel trusses interlaced with cross braces giving the tunnel supports the required stiffness. Tunnel surfaces and corners were located by measuring and laying them out with optical surveying instruments.

The building site chosen was formerly a farm, situated at a considerable distance from any highways and centered amidst a grove of trees to block high winds. Heating and air conditioning for the building are provided by a forced-air circulating system that originates in an area beside the tunnel. The air is drawn through two air-conditioning units, which heat or cool it as required, and is discharged through ducts over the top of the tunnel. The air passes across the top, down the far side, and returns under the floor of the tunnel, back to the air-conditioner area. In this way, the tunnel is surrounded by a blanket of air at uniform temperature and its temperature remains constant without the need for air currents passing through it.

Incandescent lights are used throughout the building for illumination. Flourescent lights were avoided because of the possibility of noise being introduced into the microwave or electronic circuits. The entrance to the building, both

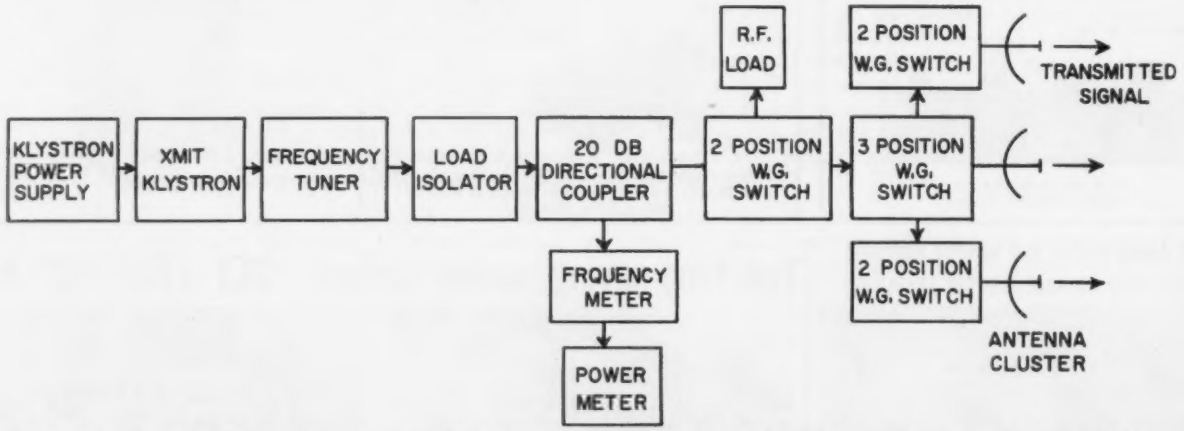

Fig 6 Block diagram of transmitter circuits. The klystron power supply is located in the operating console, and the klystron and microwave components are located on the transmitter stand. The power supply is turned on and tuned. The klystron is tuned through its own adjustments, and the adjustments on the associated microwave components until its output is peaked at the correct frequency. Klystron power output is indicated both on a meter on the stand and on a duplicate meter in the console in view of the operator. Microwave power is fed to a two-position waveguide switch which can transfer the power to either the antenna or a dummy load, then to a three-position switch used for selecting the dish to be tested. Two additional two-position switches are used in the feed to the outer two dishes to select the path for coupling to a transmitting antenna or a receiving antenna cluster. Both are operated as a transmitting antenna during the boresighting operation.

A running time meter and a cooling fan function simultaneously with the klystron heater circuit when the power supply is turned on. This is done by bringing leads from the power supply out through a special connector built into the power supply panel. The running time meter provides an indication for the remaining life that can be expected from the klystron tube. Air from the cooling fan is directed at the klystron to help cool it and prolong its life. The operating temperature is sensed by a thermocouple mounted on the klystron body and indicated at the control console.

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Accuracy (Max Error from E.2.)	5 minutes	5 minutes	20 seconds
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Excitation (400 cps)	60 volts	60 volts	115 volts
Transformation Ratio (Rotor to Stator)	980±.020	980±.010	980±2%
Phase Shift	7.5 lead	8.5 lead	0°±1 min

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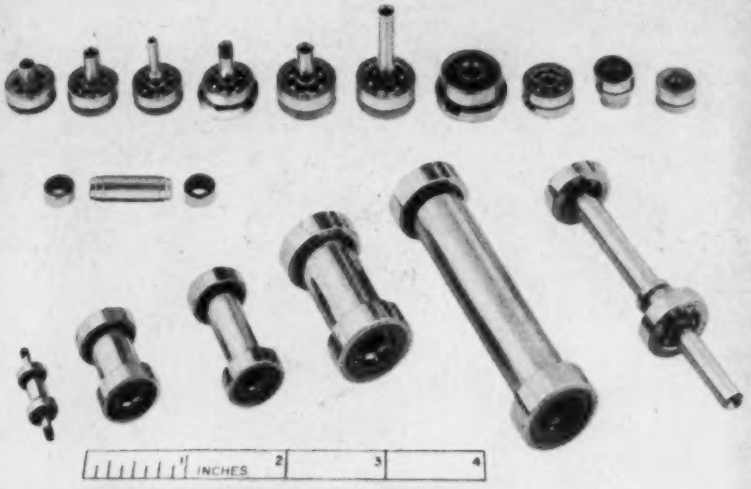

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Output:	12.4 H.P., 11,600 RPM
Weight:	17.72 lbs.

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Output:	0.15 H.P., 5,300 RPM
Weight:	4.75 lbs.

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Output:	1/400 H.P., 10,500 RPM
Weight:	3.5 oz.

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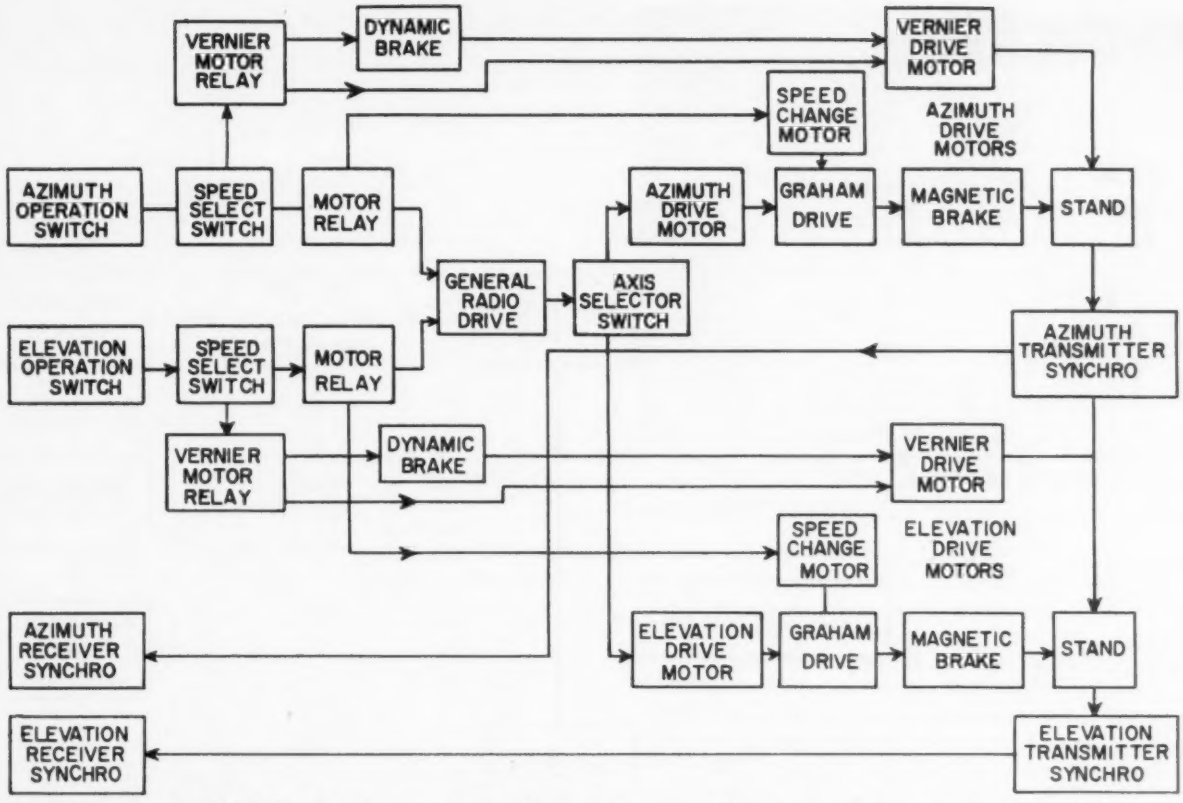


Fig 7 Block diagram of pedistal drive system. As shown, there are two separate drive systems for each plane of motion, a high-speed drive using a General Radio variable speed motor control and a separate vernier drive for the fine slow-speed control. A Graham variable speed drive is used as a two-speed geared reducer. Its ratio is changed by a motor located on the drive case which rotates the speed change shaft. A cam on the shaft trips a limit switch at either the high-speed or low-speed position desired and the drive then remains at a fixed ratio determined by the cam seting. In addition to the fixed positions, the G. R. drive provides a continuously variable speed change in each of the two speed positions selected. One G. R. drive control is used for the motors in the two planes of motion. Its input and output circuits are selected by an axis selector switch which completes the circuit only for the axis selected. A magnetic brake locks the drive to eliminate coasting and to hold the stand in a fixed position against unbalanced weights.

In operation, the speed selector switch is thrown into either high-speed G. R., low-speed G. R., or vernier position, and the axis selector is switched to the plane of motion desired. The drive is then operated by a vertical lever switch with a forward and reverse position, both sprung to the off position. In either G. R. drive position, the motor is actually controlled by a relay to prevent heavy currents from passing through the switch contacts. The speed change motor on the Graham drive is interlocked with the drive switch so it operates only when power is suppled to the drive motor.

The vernier motor drives the stand through a limited motion (0.050° in one minute) by means of a long linkage bar, providing an extremely slow speed drive for final nulling. It is a two-phase worm geared motor controlled directly by the operating switch. The axis selector switch is not used in this circuit. The vernier motor is prevented from coasting by a dynamic brake which applies direct current to one motor winding when operating power is turned off.

Each axis of each stand turns a position transmitting synchro connected through a gear ratio of 36 to 1. This synchro feeds information to a receiver synchro located in a display panel on the operating console. By this means both planes of both stands can be quickly driven to the preset position for any dish on either a transmitter or receiver antenna cluster by operating the stands until the synchro indicators point to the right dial preset markings.

A number of circuit interlocks provide for safety of the equipment and the convenience of the operator.

for personnel and equipment is constructed in the form of a closed vestibule to provide an air lock. It is equipped with doors both to the outside and inside so that entrance can be gained by opening one door at a time, thus preventing drafts and air currents which would upset temperature uniformity.

ELECTRICAL EQUIPMENT

The electrical equipment, comprising the stand drive circuits, and the microwave and electronic circuits, is located in four areas: (1 and 2) the two test stands, (3) an operating control console located at the transmitter end of the building and (4) an electronic rack located near the receiver stand. Fig 7 is a block diagram of the drive circuit. This diagram shows the equipment for one stand only, the other being identical. Figs 6 and 8 are block diagrams of the electronic circuits for the transmitter and receiver stands, respectively.

ALIGNMENT OF STANDS

Precise alignment of the electrical and mechanical components of the two stands was one of the most critical requirements and the one most vital to the success of the program. The techniques used were unique when compared to similar processes requiring lesser degrees of accuracy.

Transmitter stand alignment is primary in this technique because it establishes the boresighting reference lines by measuring from reference lines in the antenna structure that are to mate reference lines in the aircraft. For this purpose Wild T-2 Theodolite is mounted to a large cast aluminum alloy mounting fixture, which is also the mount for the antenna clusters during "boresighting", and this fixture is kinematically mounted to the face of the transmitter stand. Except for their physical size the mounts for transmitting and receiving antennas are identical. On the

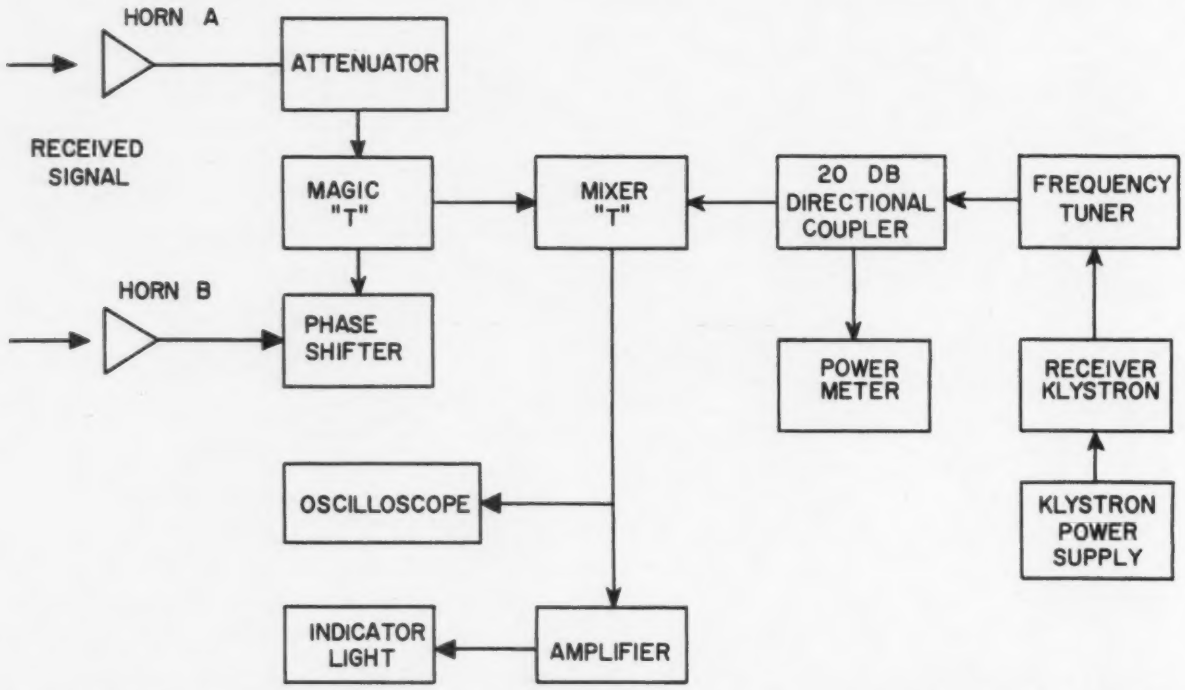


Fig 8 Block diagram of receiver circuits. A klystron is used at the receiver stand as a local oscillator. It is tuned to a frequency of 30 mc higher than the transmitter klystron, producing a 30 mg beat with the signal picked up by the receiver horns. The diagram shows use of one pair of horns, forming one signal channel. A total of eight channels are used with four horn pairs arranged horizontally and four vertically. The other seven circuits are identical with the one shown, the only difference being that one local oscillator klystron feeds the eight mixer T's by means of power divider microwave circuits. The klystron power supply is turned on at the console, tuned and adjusted for output power in a manner similar to that of the transmitter klystron, and connected to a running time meter and cooling fan by means of an identical circuit. The receiver klystron is adjusted at the power supply to oscillate at a frequency swept through a range of 2 mc with a low frequency saw-tooth sweep. This eliminates the requirement that both klystrons operate with an ultra stable output to maintain a stable I. F. amplifier signal. It also provides a baseline on an oscilloscope for observing the output and makes the error signal observed appear as a pip on the baseline.

The signal from the transmiter stand is received by the pair of horns shown in the drawing as A and B. Any difference in either the amplitude or phase of the signal received appears as a resultant signal which is fed into the mixer T. Here it combines with the swept frequency output of the local oscillator klystron producing a frequency modulated 30 mc 1. F. frequency signal. This signal is amplified and detected in the I. F. amplifier and appears at the output as a vertical pip superimposed on a baseline, repeated at a 60 cps repetition frequency.

Output signals of all the I. F. amplifiers are carried through the building in coaxial cables back to the console. Six of the eight channels (those of the three innermost pairs of horns on each axis) are then fed into low frequency transistorized amplifiers. The outputs of these amplifiers close relays lighting panel indicator lamps which serve as visual indicators of error voltage present in the corresponding receiver horn pairs. The remaining two I. F. amplifier output signals (those from the outer-most pair of horns on each axis) are connected to oscilloscopes for visual display of the error signal shape. In normal operation, the oscilloscopes are connected to observe the outer horn pairs, but by means of selector switches, they can be connected to monitor the error signal of any horn pair channel. The oscilloscopes are required in the circuit of the outer pair of horns during operation to provide sufficient sensitivity to assure meeting the beam angle tolerance required. The indicator lights are incorporated to provide quick reference to show if the stand is out of position by a large amount such as a multiple of a half wavelength.

forward end of the antennas, on both the left and right-hand side, is a spherical bearing mounted in a cup. This bearing contains a hole to receive the mounting stud on the test stands. The stud is a facsimile of those used in the B-58 Hustler Aircraft. On the aft end of the antennas is a single smooth stud whose axis is at right angles to the axis of the holes in the spherical bearings. In the B-58 Hustler Aircraft, this stud slides into a hole in a spherical bearing fastened to the aircraft. On the test stand, this stud is set into a "V" block with a clamp that bears against the stud to seat it well (Fig 9).

The shoulders on the two mounting studs that bear against the spherical bearing, must be perfectly aligned to each other in height and to the surfaces of the "V" block so that the proper attitude of the antenna cluster's beams can be maintained when the antennas are mounted in the B-58 aircraft.

The faces of the transmitter test stand and the aluminum mounting fixture are adjusted roughly parallel to each other, and then both are rotated in elevation until plumb. Then the Theodolite, with a striding level affixed to it, is rotated through the major points of the compass and adjusted until the collimation level and striding level show closely the same degree of level. In other words, until the azimuth axis of the Theodolite is plumb and the telescope barrel is level to the earth. Next a 90° prism, or optical square, is fitted on the objective end of the scope so that it can be rotated about the axis of the telescope barrel enabling a viewer to sight on objects 90° from the axis or line of sight.

In the final step, optical scales are fitted against the

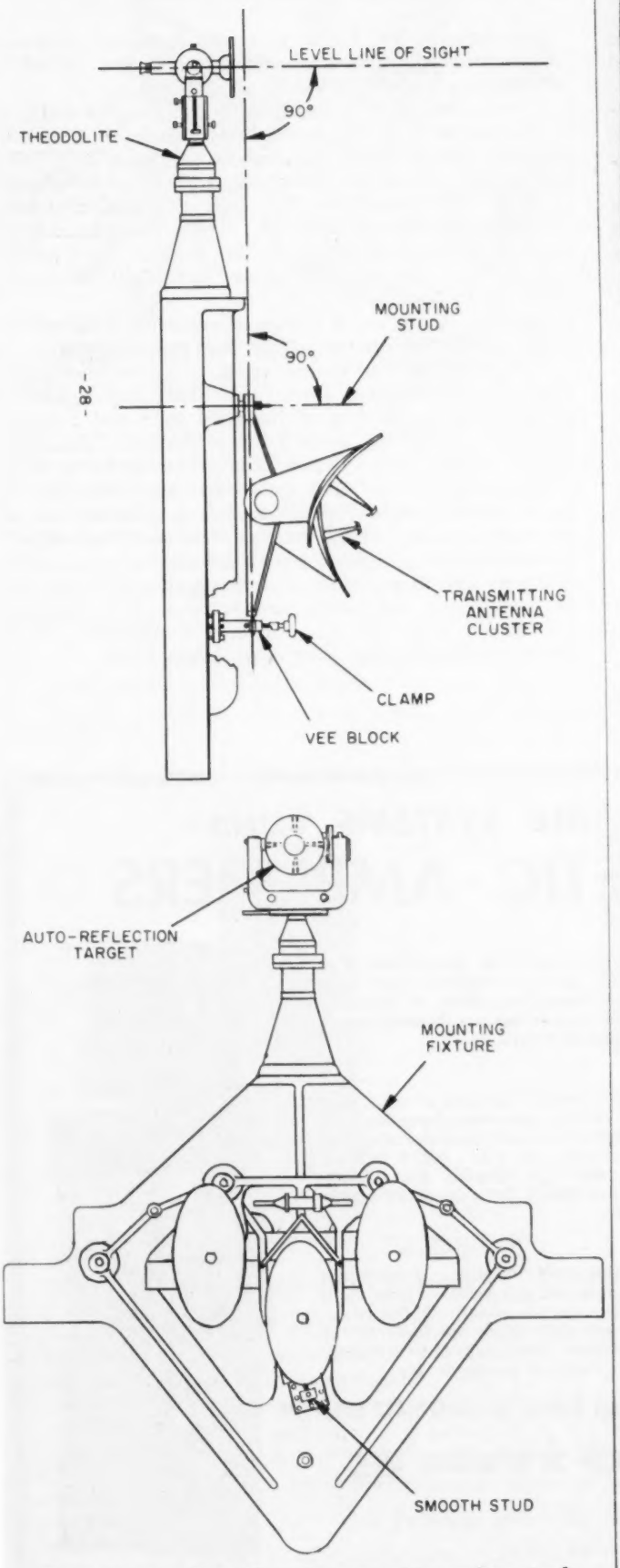
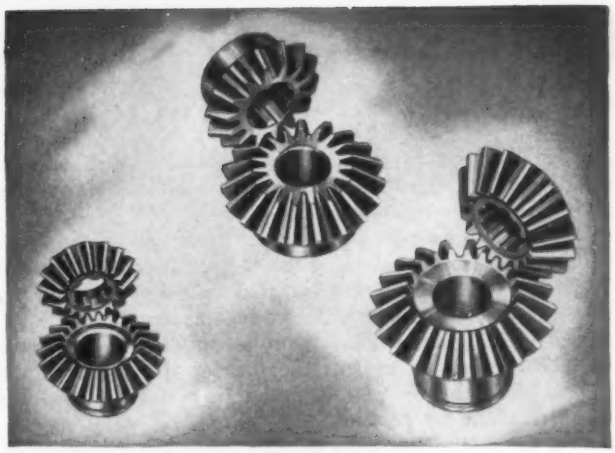


Fig 9 Diagram illustrating alignment of transmitter stand.



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bearing shoulders of the antenna mounting studs and on the "V" block, and the mount is adjusted until an equal arbitrary value is sighted on the scales.

The basic techniques for aligning the received stand are similar to those for aligning the transmitter stand. The object was to align the stand so that the faces of the array of 16 receiver horns would lie in one plane within a tolerance of 0.002 inch, and so that the optically flat surfaces of the 6 mirrors, as well as the face of the stand, would be parallel with the plane of the horn faces. Also the mirrors had to be positioned on the stand at spots corresponding to the locations of the theodolite image when each of the three transmitter and three receiver antennas was being tested.

Then, for each antenna tested, when the transmitter stand was rotated with respect to its zero reference position to the angle prescribed for that antenna, and when the orientation of the receiver stand was adjusted until the theodolite image was centered, the plane of the horn faces at the receiver stand would be normal to the prescribed direction of the antenna beam.

The receiver stand face and horns were aligned by means of a K and E optical telescope with a 90° angle prism mounted on the stand at the center point between the horns. Auto-reflection measurements by means of the theodolite on the transmitter stand were used to align the mirrors.

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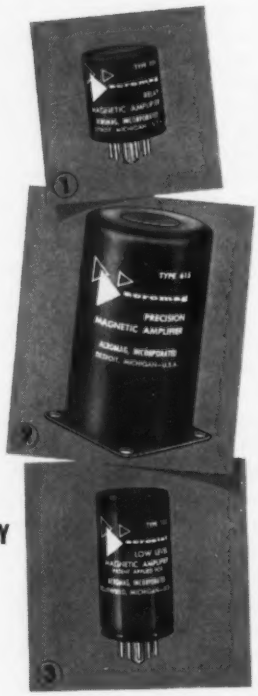

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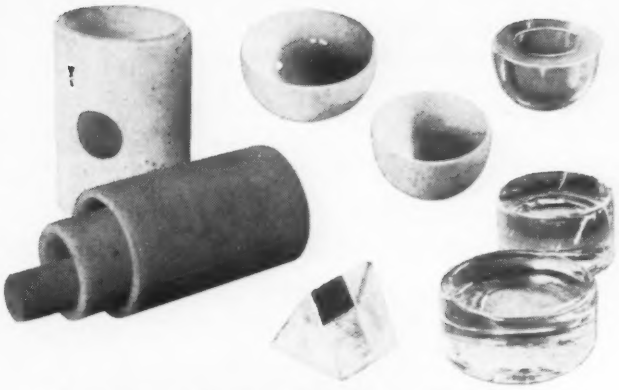

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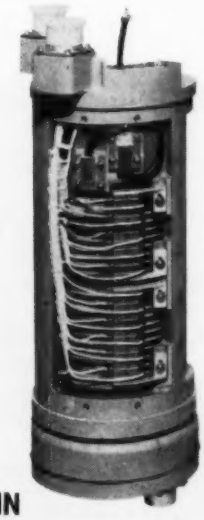

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vernistat® design report

Information on Vernistat a.c. potentiometers for design engineers

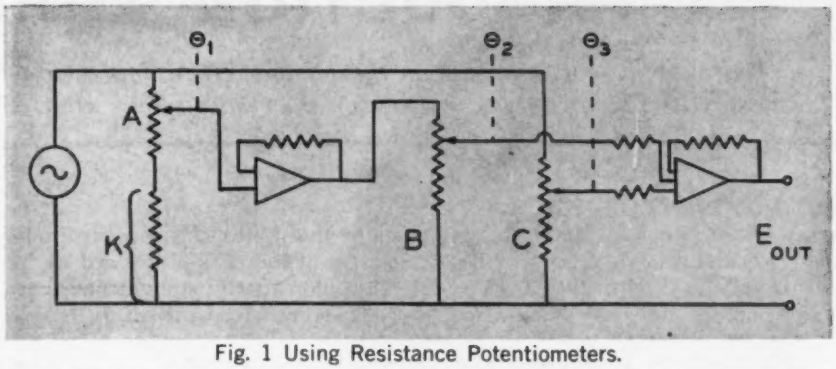

Fig. 1 Using Resistance Potentiometers.

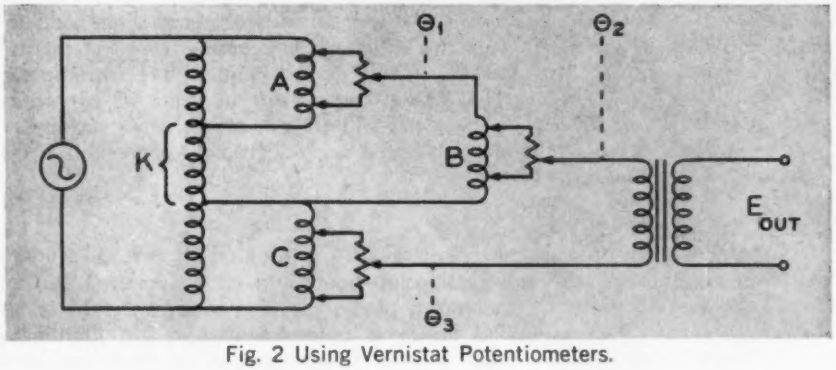

Fig. 2 Using Vernistat Potentiometers.

HOW VERNISTATS SAVE AMPS AND AMPLIFIERS IN A COMPUTER STAGE

Here's a whopping good example of an equation solved by two different circuits. It multiplies three variables (shaft angles) by three constants and throws in a couple of additions and multiplications for good measure:

$$E_o = (K + A\Theta_1) \cdot (B\Theta_2) + C\Theta_3$$

At a glance you can see how the use of Vernistat precision a.c. potentiometers simplifies the circuit.

Due to the high output impedance of resistive pots, an isolation amplifier is required in the multiplication section of the circuit in Figure 1. For addition, summing resistors are used in conjunction with a feedback amplifier. The system is accurate enough, but it suffers on two counts: 1. the amplifiers chew up power and throw off heat; 2. use of the amplifiers reduces the circuit's reliability, since reliability is a function of the number of elements in a system.

No isolation amplifiers are needed, thanks to Vernistat's high ratio of input to output impedance. Addition is accomplished simply by using phase reversal in an input transformer. By eliminating amplifiers, the Vernistat gives you reductions in size, weight, power supply requirements and heat rise.

Don't overlook other advantages of the Vernistat. This remarkable, new circuit element provides high linearity, low phase shift and precise voltage division. It takes ten turns of the shaft to cycle through its voltage range, and the shaft may be turned **forward**, instead of backward, to its starting point.

If you're looking for high resolution with practically no background of phase-shift "noise" (quadrature), Vernistat a.c. potentiometers are for you! Make sure you get a full rundown on their construction, specifications and applications by writing to us.

If your business involves design of analog computers, servos, and other controls—then resolve to look into the Vernistat picture immediately! Our literature may help you soar to new levels of design thinking. Write now!

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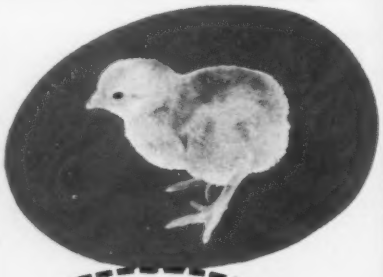
SIZE II VERNISTAT AC POTENTIOMETERS

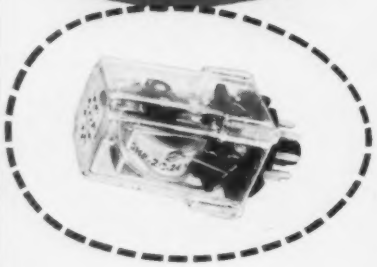
These miniature, ten-turn components are approximately 1⅔ inches long, a little over an inch in diameter, and weigh only 2 ounces. The Series 4 operates at 400 c.p.s. at 20-40 volts maximum input. Input impedance is 2,500 to 30,000 ohms; output impedance, 40 to 200 ohms. Terminal conformity is ±0.05%. Series 4 Vernistats are 10-turn units and provide continuous rotation, since they have no stops.

Four Series 4 Vernistat models are available which cover the above ratings. They are useful as data transmitters, computer elements, driving elements for resolvers, servo follow-up components... for mathematical operations, voltage step-up, and phase reversal. Write for complete data on these high-precision components today!

vernistat division
PERKIN-ELMER CORPORATION
768 Main Avenue, Norwalk, Connecticut

which comes first...





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GHA — 5 amp resistive contact rating
GHB — 10 amp resistive contact rating
GHE — 5 amp plate-circuit type

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GHA and GHB AC pull-in power is from 2 to 3VA; DC from 1 to 2 watts

GHE pull-in power is from 130 to 350 MW depending on contact arrangement

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Open relays available with solder lugs or printed circuit tabs

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If you want more information on the production aids discussed below write the appropriate number on the reader service card.

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are produced by an automatic welding machine that butt-welds a predetermined length of lead wire to a slug of larger wire, providing a 2-piece lead of high reliability. The 2 wires feed from spools, are automatically straightened, cut to proper lengths, and then welded. Kahle Engineering Co., Union City, N. J.

SEMICONDUCTOR TEST CHAMBER **853**
accommodating 18,000 devices simultaneously, is said to assure unprecedented, proven reliability of mass produced quantities of semiconductors. The thermal-electrical system subjects the devices to high or low temperature conditions in conjunction with electrical load for periods equivalent to years of operational stress. Slots are provided for ninety 10" x 18" etched circuit cards on each of which up to 200 specimens can be mounted and electrically connected. Wyle Mfg. Corp., El Segundo, Calif.

INSPECT SMALL PARTS **854**
with Syl-A-Scope, an optical instrument which provides rapid, precise examinations of points and tips of very small components and tools (under 1/32 inch in dia). To use this device a technician places the part in an aperture on the Syl-A-Scope plate. The magnified image is reflected upon a big illuminated screen. The operator can then make a rapid examination of the part's condition. Robins Industries, Flushing, N. Y.

FLO-MOTION SHAFT ROTATION DETECTORS **855**
monitor any points in a conveying, handling or processing system such as totally enclosed, underground, remote automatic or semi-automatic equipment. Wired into an interlock system, the detectors provide automatic shut-off if a stoppage or excessive variation in shaft speed occurs. Variations as small as 1 rpm can be detected; instrument works in any position; input shaft turns in either direction; fail-safe feature gives warning signal if any component fails or power is interrupted; completely self-contained. Flo-Tronics, Inc., Minneapolis, Minn.

VACUUM IMPREGNATION SYSTEM **861**
enhances penetration of epoxy and phenolic resins into electrical generators. Better dielectric properties and greater dependability of stator assemblies result. Chief feature is a quick-opening, quick-closing cover which meets A.S.M.E. code. Chamber withstands 100 psig steam pressure. A special trap in evacuation line traps impregnant preventing pollution of the oil in vacuum pump operation. F. J. Stokes Corp., Philadelphia, Pa.

REMOTE SPRAY COATER **868**
with portable magazines, accurately coats axial lead components at rates of 3,000 to 10,000 per hr. A traveling disposable masking strip confines the coating to selected areas and keeps the leads clean. Operating on 110 v, 60 cycles current, unit requires 20 cfm air at 80 psi. Conforming Matrix Corp., Toledo, Ohio.

PIGTAIL GRABBER **851**
simultaneously seizes both pigtails of diodes, transistors, capacitors and resistors, making secure low-resistance electric-test connections with no bending or breaking of leads. Used for testing of small parts, the semi-automatic fixture consists of spring-loaded jaws, 1½" apart which open by pressing a handle or a treadle; the test part drops into fixture; jaws close firmly on wire leads when operating handle releases. Jaws work separately to compensate automatically for difference in wire size or position. Precision Metal Products Co., Stoneham, Mass.

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PREREGULATED POWER SUPPLIES

Forward Biased Diodes As Voltage References

M. Glasberg, *Contributing Editor*

Semiconductor diodes in the last few years have become extremely popular for a multitude of applications. One of their more interesting characteristics is voltage regulation using the back biased zener breakdown effect. However, they can also be used as voltage references in the forward direction. Fig 1 shows the forward conduction of a semiconductor diode with its equivalent circuit. This equivalent circuit is basically the circuit of a voltage reference.

Zener diodes can be made to breakdown at a variety of voltage levels ranging from about 3.3 volts upward. Forward biased diodes, on the other hand, have a fixed regulation value depending upon the semiconductor material: about 0.3 volts for germanium and about 0.7 volts for silicon. Another interesting comparison is that forward biased diodes have a negative temperature coefficient and back biased zener diodes have a positive temperature coefficient.

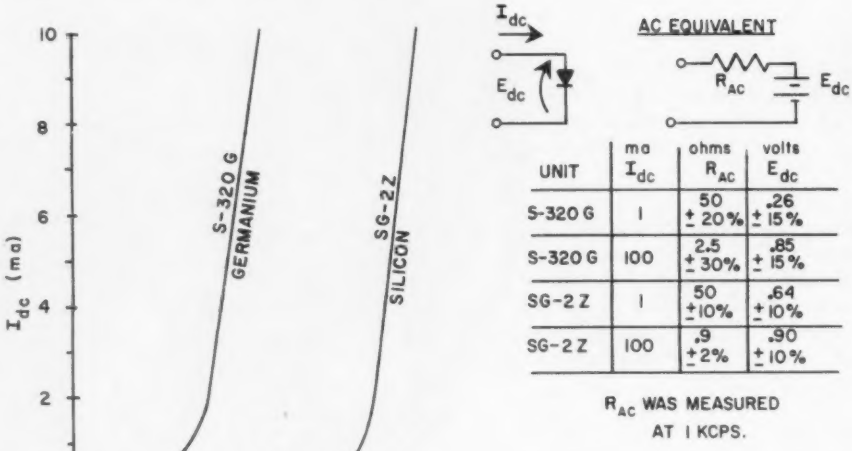

Fig 1 Forward biased diode characteristics.

STABISTORS

Transitron Electronic Corp., Wakefield, Mass. has developed a line of diodes, called Stabistors, specifically designed for voltage reference. Tranistron has published an interesting set of application notes on many of their uses. Fig 1 is based upon characteristics of two Stabistors.

PREREGULATION

One area, which has not received any attention and in which the forward biased diode is uniquely useful, is preregulation in power supplies. Fig 2 shows a simplified version of the schematic of the TP3-100 Solid State Power Supply made by the Diehl Mfg. Co., Somerville, N. J. This supply is rated for –26 to –30 volts at 1.5 amps within 0.2 percent. The preregulator is shown dotted. This circuit is extremely important for a number of reasons:

a. it reduces the error due to the rough dc voltage changes.
b. it reduces the ripple introduced into the regulator.
c. it reduces the no load current required by the first transistor and, therefore, its maximum dissipation.
d. it increases response and recovery time.

The reason why the forward biased diode is so useful as a preregulator is its control at low voltage. The smallest low cost zener is 6.8 volts (units as low as 3.3 volts are available, but at about twice the price) which means

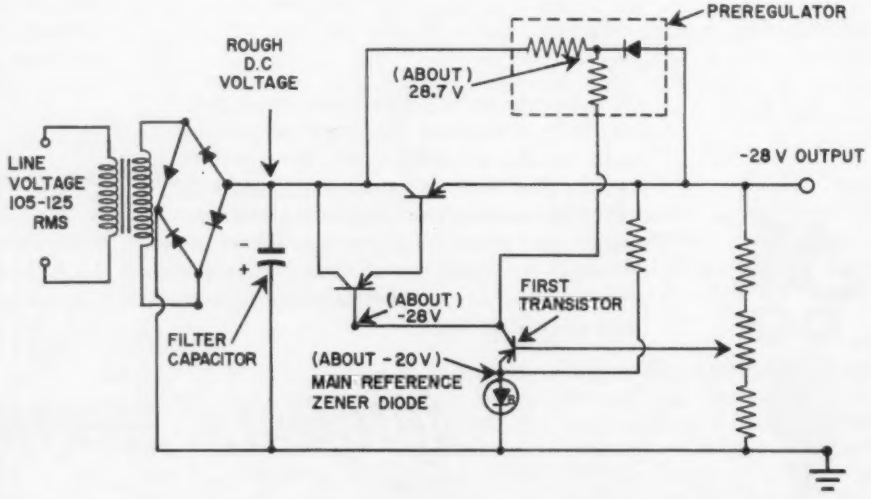

Fig 2 Simplified schematic of power supply.

that the rough dc across the filter capacitor cannot decrease below 28 + 6.8 = 34.8 volts without the preregulator losing control. This characteristic is a very important consideration because the transformer must be designed to have high enough voltage so that, for minimum line voltage and maximum current, the rough dc will always be greater than 34.8 volts. With this safeguard, however, the dissipation across the series regulating transistor for maximum line voltage can be very high. As in any transistor circuit, increased power dissipation is a serious problem because it cannot be sustained without added expense, size and degraded performance. For example, to keep 34.8 volts at 105 volts rms of line voltage you might get as much as 45 volts at 1.5 amps for a line voltage of 125 volts. The maximum dissipation could, therefore, reach (45–28) 1.5 = 25.5 watts.

With a forward biased silicon diode as a preregulator, the rough dc could be allowed to decrease to 28+0.7 = 28.7. This would reduce the maximum dissipation at 125 line volts and 1.5 amps to about 16.5 watts.

You may wonder why the preregulator cannot be tied directly to ground instead of to the 28 volt output and adjusted to say 29 volts with a 29 volt zener. Three important zener characteristics reveal the answer:

- **dissipation:** a zener to regulate well must start with a fair amount of current which could mean considerable dissipation at 29 volts. The forward biased diode, at 0.7 volts, can conduct a great deal of current without any dissipation problems. This large current, of course, increases its regulating accuracy.
- **limits:** zener diodes can be chosen with a ±5 percent, ±10 percent or ±20 percent variation in their breakdown voltage. Variation of ±5 percent at 29 volts is ±1.45 volts. This is completely unsatisfactory, especially since the output can be as high as 30 volts. Forward biased diodes can be tied to the output so that the preregulator voltage will always be slightly higher than the output voltage and will always operate. Stabistors, in fact, can be obtained with ±10 percent variation in their regulating voltage.
- **cost:** the cost of zener diodes goes up considerably with low variation in breakdown voltage. One of the greatest advantages of the forward biased diode regulator is its price, anywhere from 1/2 to 1/10 the price of a zener diode.

For more information on Stabistors:
Write No. 164 in Box on Inquiry Card
For more information on Preregulated Power Supplies: Write No. 171 in Box on Inquiry Card

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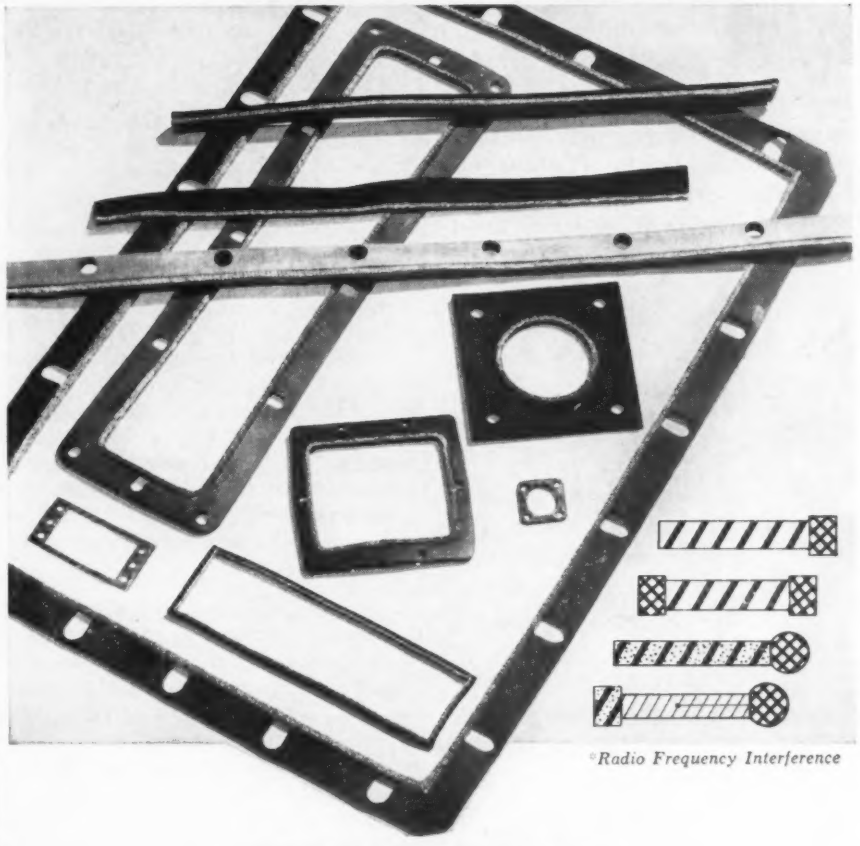

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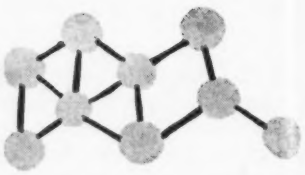
CIRCLE NO. 77 ON INQUIRY CARD

by David Bandel *Staff Columnist*
Associate Technical Director,
TRACERLAB, INC.



MATERIALS

Fuel cell development appears to be moving in the direction of specialization. Perhaps this in an indication of growing maturity. The more exotic types have less of an economic hurdle to mount than the fuel systems being developed for more conventional applications. In military and specialized civilian applications performance and package size can override simple economic considerations. One of the exotic fuel cells being developed is based on a sodium amalgam-oxygen fuel system. Sodium amalgam is an alloy of sodium and mercury. M. W. Kellogg is developing a prototype of this type of cell rated at 75 kw. Initial studies were conducted by Dr. Ernest Yeager of Western Reserve University. The chief advantages of this cell over the hydrogen oxygen, or hydrox, cell are a higher open-circuit voltage, (2v vs lv) a higher capacity to volume ratio and a weight approximately 15 times less than a silver-cadmium battery. The sodium-oxygen cell operates at atmospheric pressure and 140°F. Energy output is between 2 and 3 lbs per kwh.

An experimental natural gas fuel battery has been built by the Institute of Gas Technology. Chemistry of the cell is rather complex but low cost and availability of the fuel makes this system attractive as a packaged power source for locations where natural gas is available and other sources of electrical energy are not handy. The electrolyte is a mixture of molten sodium and lithium carbonates held at 600-800°C in a porous nickel diffusion anode. Lifetime of the present cells is short, since molten carbonates are quite corrosive and decompose at the operating temperature unless an atmosphere of carbon dioxide is maintained. It is estimated that in many parts of the country energy as natural gas costs one sixth as much as electrical energy. In these regions, home type units of 10 kw capacity would be economically feasible and a 10 kw power pack would be about the size of a gas furnace.

One obvious use of thermoelectric generators is as a device for squeezing more energy out of thermal engines or other devices that produce "waste" heat. Steam turbines, combustion engines and steam plants all generate "waste" heat that must be rejected. General Electric engineers have combined a thermoelectric converter with a thermionic converter to salvage the "waste" heat. The result is approximately twice the power output and efficiency from such a system with no additional heat input to the thermionic converter. With further development the cascaded devices can be used for power supplies in ships and navigational aids where a heat sink of 100°F or lower is handy.

Two new lasers, or optical masers, have been devised by Dr. P. P. Sorokin and Dr. M. J. Stevenson at IBM. These lasers are based on calcium fluoride crystals doped with small amounts of uranium (III) or samarium (II). Light emitted by these crystals is excited by a xenon discharge lamp and is a highly coherent beam in the visible and infrared part of the spectrum. The beam is highly directional with a spread of less than 0.01 radian, which is a pretty tight beam by present microwave standards. Some comparisons with the ruby laser are interesting. The calcium fluoride laser operates on less than 1/500 the power required by the ruby. The light produced by the ruby laser is emitted in short pulses at widely spaced intervals while the light emitted from the calcium fluoride laser is continuous. The radiation emitted by the calcium fluoride laser is concentrated in a single frequency. The uranium (III) doped crystal emits radiation at 2.5 microns, well into the infrared portion of the spectrum, the samarium doped crystal 0.708 microns.

The lowly light bulb is about to become a molecule splitter by way of increasing light efficienmy. A new type of light bulb uses the dissociation of molecular hydrogen to increase the light output. Theoretical efficiency is 60-70 lumens per watt, about 5 times that of the present incandescent lamp. In this lamp, hydrogen molecules are dissociated on a hot tungsten filament into atomic hydrogen. The atomic hydrogen is recombined on a phosphor-coated surface, where a large proportion of the recombination energy is released as light.

ELECTRONIC MATERIALS

Dr. R. C. Vickery and H. M. Muir, co-discoverers of the recently announced thermoelectric material gadolinium selenide, have formed a new company to prepare, and conduct research and development studies in advanced materials for space-age technology. The thermoelectric properties of gadolinium selenide were announced at the American Rocket Society Space Power Symposium in Santa Monica in September 1960, and were reported in our Nov., 1960 Materials Section by Staff Columnist Dr. David Bandel. Thermoelectric materials will, however, be only part of the interests of this new Corporation which will enter electronic, magnetic, energy conversion, high-temperature and rare element materials fields.

Located in Santa Monica at 2200 Colorado Avenue, Electronic Materials Corporation is fully equipped for and will conduct research on materials of high interest to governmental and industrial agencies. Their facilities include an extensive and well-instrumented laboratory allowing investigation and analysis into every aspect of the solid state.

Dr. Vickery, President and Director of Research of this new Corporation, has an international reputation in the general areas of materials and their application, and specifically in the rarer element field in which he has worked in England as consultant, and in Australia with the Australian Government. On coming to America in 1955 Dr. Vickery was, for three years, Head of the Chemistry Department of Horizons Incorporated, Cleveland, and then most recently was with Nuclear Corporation of America, where he directed research and development activities in thermoelectric, electronic, and magnetic materials studies. He holds doctorate degrees from the Universities of Oxford and London, has published over one hundred papers, four technical books, and holds twenty-five patents. Consultant to government and industry, Dr. Vickery has lectured and written widely on advanced materials and application concepts, and functions as a Staff Columnist for Electromechanical Design.

Dr. R. C. Vikery, ELECTROMECHANICAL DESIGN Staff Columnist, who is now President of Electronic Materials Corporation.

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Epoxides

Unox 201, 206 and 207 are said to be the only commercial epoxides with cycloaliphatic structures which give the materials a resistance to discoloration from ultra-violet light, heat and air oxidation. Unox 201 has a low viscosity at room temperature without the use of special solvents or reactive diluents that would normally enter into the reaction and degrade the properties of the cured plastic. Because of this low viscosity, voids in castings are filled, bubble formation is reduced and better penetration of both glass fiber laminates and prefilled molds are permitted. Among the many applications where Unox epoxide 201 can be used include: electrical and electronic components, encapsulation, tooling coatings, laminates, and adhesives.

Unox 206, a diepoxide, serves as a reactive diluent for epoxy resins derived from either Unox epoxides or the bisphenol-A-epichlorhydrin types, reducing the viscosity of epoxy resins without degrading their important properties. Unox epoxide 207 forms epoxy plastics that are said to have excellent high-temperature physical and electrical properties. The low combining weight provides added savings when used to cross-link or modify low cost resins and polymers. Unox 207 can be converted readily to a "B" stage resin in either a solvent or dry powder form, having a shelf life of more than six months. These stable "B" stage resins are ideally suited for impregnating glass fibers and subsequent lay-up laminating. Union Carbide Chemicals Co., New York, N.Y.

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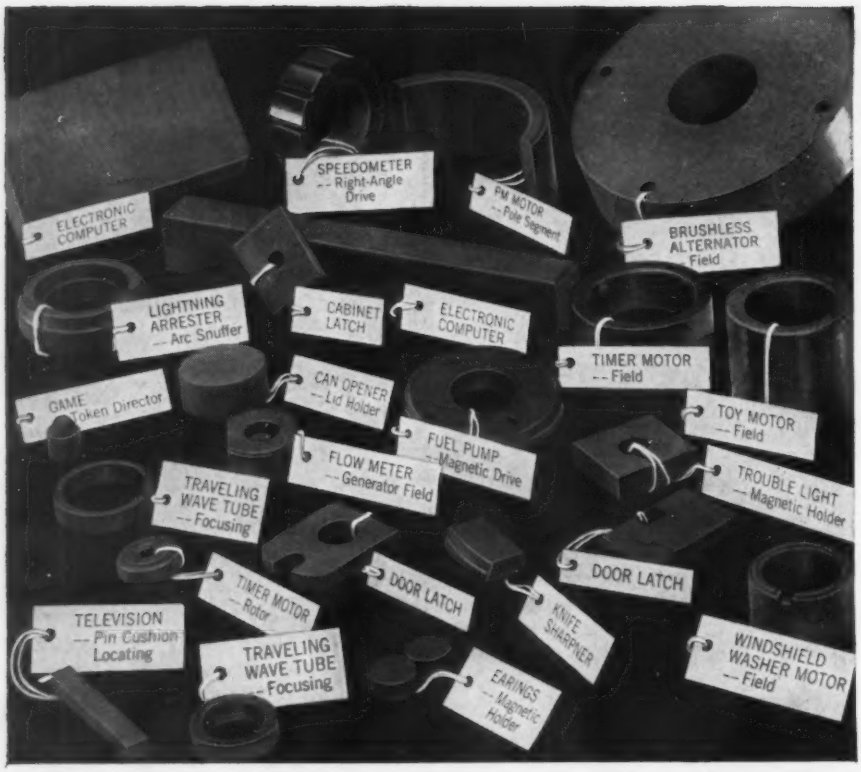

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MATERIALS

Gasket Material

Recommended for its stability to corrosive gases and liquids under both high and low temperature conditions, an improved fiber-reinforced, nitrile rubber gasket material called Vistex III is said to have 100 percent compression recovery; exceptional tensile strength; resistance to oil and aromatic fuels and good flexibility. Especially well suited for gaskets where light weight is a factor, one square yard of 1/32 inch Vistex weighs only 30 ounces. It can be precision cut or punched into gaskets, strips or washers. American Felt Company, Glenville, Conn.

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Reinforced Teflon

Wire insulation made from a new type of fluorocarbon resin, Teflon, offers improved resistance to abrasion, plastic flow, cut-through and heat. The insulation, called Type AR, consists of mineral-fiber particles added to Teflon. The particles average about one micron in diameter and 500 to 1000 microns in length. Orientation of more than 90% of the fibers parallel to the wire surface (random orientation would average about 50%) supports concentrated loads and resists penetration of sharp edges. This eliminates the need for glass fiber wrapping or braid for surface protection, resulting in a reduction of space and weight and providing an all Teflon insulation with uniform dielectric properties. W. L. Gore & Associates, Inc., Newark, Del.

Write No. 613 in Box on Inquiry Card

Conductive Gaskets

Designed for high temperature uses, recently developed conductive basketing made from silicone rubber and metal material conforms easily to irregular surfaces and is impervious to fluids. The two types available withstand temperatures from 65 to 500F. These conductive gaskets are recommended for use where a current flow between two metal surfaces is needed, and where induced radio frequencies need to be restricted or filtered. They are suited for wave guide gasketing, for shielding between magnetos and their bases, in ignition harnesses, in quick disconnect plugs, and in telecomputing equipment. The Connecticut Hard Rubber Co., New Haven, Conn.

Write No. 604 in Box on Inquiry Card

ENGINEERING NEWS-#8

SIX PUSHBUTTON SWITCHES

CHECKED	ENGR.	CONTROL SWITCH DIVISION

SUB-SUBMINIATURE

B7000 is only 11/32" diameter, 1¼" total length. Available with a bushing or flange mounting. Flange can be engraved. Anodized aluminum case, plastic plunger cap and solder lugs. Rated 1 amp at 28 VDC. The perfect pushbutton for subminiaturized instruments and control panels.

MOISTURE-PROOF, 6 CIRCUIT TYPES

W100 is available at S.P.S.T. (N.O. or N.C.), S.P.D.T., 2-circuit, and 3-terminal (N.O. or N.C.). Designed to MIL-S-6743, MS-25089. Completely moisture-proof and enclosed in anodized aluminum case with silicon rubber boot. Available with any of 8 mounting adapters (Adapter P shown) to meet any mounting or panel requirement. Rated 10 amps at 28 VDC resistive.

LOW COST, U.L. LISTED

B2000 series switches are considerably smaller than standard ½ amp momentary pushbuttons, yet cost much less and actually are U.L. rated at 8 amps, 120 VAC. Select S.P.S.T. circuit either N.O. or N.C., with solder lugs or pigtail leads. Mounts in ½" dia. hole.

WITH OR WITHOUT LIGHT

WC1500 is a very small moisture-proof switch (designed to MIL-S-6743) with a minimum life of 25,000 operations at rated load. Available with or without indicator light in pushbutton, and rated at 2 amp ind. or 4 amp res., 28 VDC. D.P.D.T. or 4-circuit. Mounts in ⅜" diameter panel hole.

MOISTURE-PROOF, ALTERNATE ACTION

J3136 is a new moisture-proof switch originally designed for military ground support and aircraft equipment. Two-circuits, rated at 5 amp ind. or 10 amps res. at 28 VDC: 5 amp (.75 P.F.) ind. or 10 amp res. at 120 VAC. Life is 25,000 operations min. at rated load. Anodized aluminum case with solder lug terminals, and 8 styles of mounting adapters available. Mounts in ⅜" dia. hole.

20 AMPS., PUSH-PUSH

J100 is a S.P.S.T. switch rated 20 amps res. at 28 VDC; 10 amps res. at 115 VAC. Ruggedly built to give compactness and durability under critical operating conditions. Weighs only 1 oz. Total plunger travel is only ¼". Overall size: 1" diameter, 2 15/32" long.

The switches shown above are merely samples from the full line of CONTROL SWITCH pushbuttons. Perhaps one of these is a solution to a switching problem you face. If not, write for your **free** copy of CATALOG 100 for details on the wide range of switches available, including basic switches, toggles, lighted pushbuttons, indicator lights and many other types.

CONTROLS COMPANY OF AMERICA

CONTROL SWITCH DIVISION

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Manufacturers of a full line of switches, controls and indicators for all military and commercial applications. All standard units stocked for immediate delivery by leading parts Distributors.

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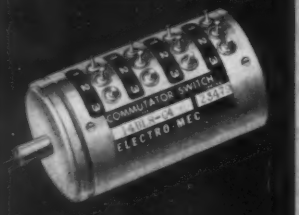
over 10 years
experience
in building
Precision
POTENTIOMETERS
and
DIGITOMETERS
we are now
offering to you
the **NEW**

ELECTRO-MEC
Rotary Switch



You will find
the same
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of workmanship
resulting in
heretofore
unobtainable
ACCURACY.

This switch is
presently used in
aircraft and missiles.

Available in single or multi-gang assemblies and/or in combination with potentiometers of all sizes.

Certified calibration data supplied with each instrument.

For Engineering Data Sheet giving further details, please write
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Teletype: NY4-2126

ELECTRO-MEC
Division of WALTHAM Precision Instrument Company, Inc.
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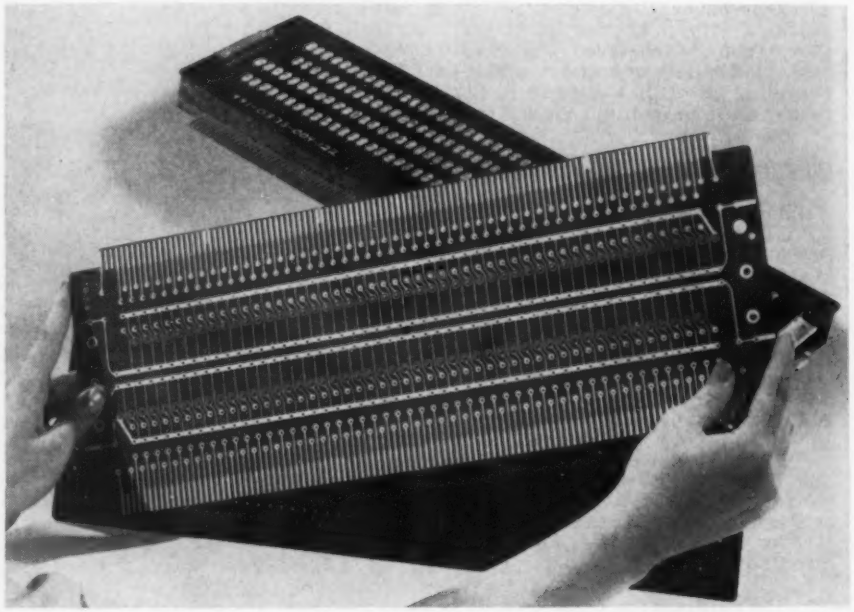
TESTING



Hole patterns in Fotoceram, which is derived from photosensitive glass, are obtained by chemical machining. Metallized areas can be subjected to soldering more than 50 times without damage.

CAPACITOR RELIABILITY

Accurate Repetitive Measurements From Improved Test Circuit Boards

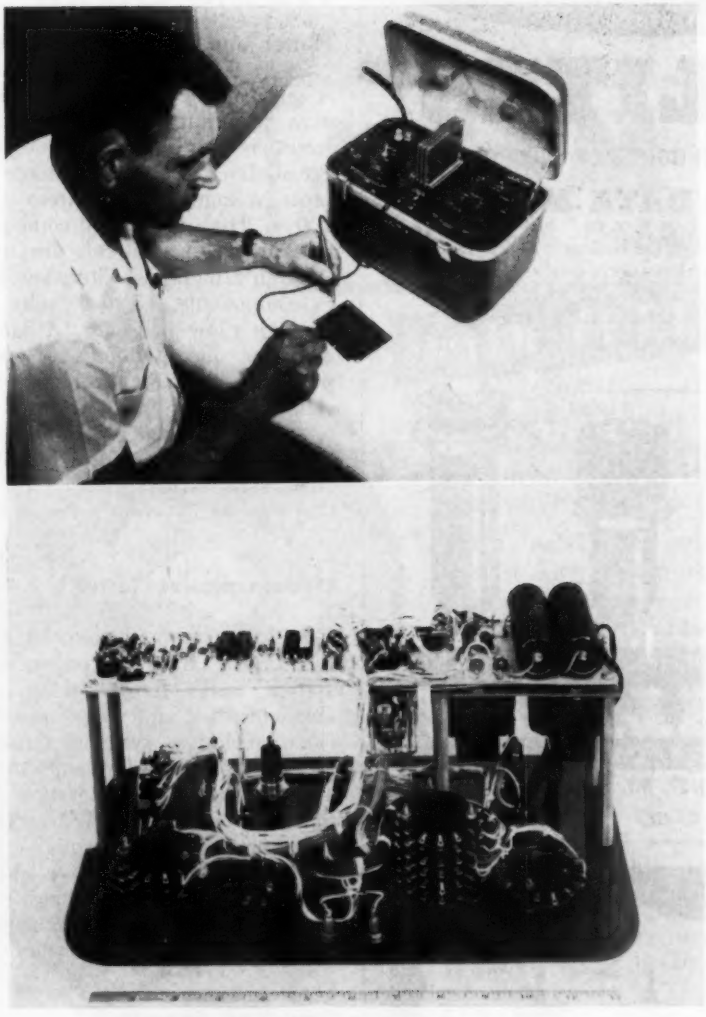
Capacity is measured 10 times more accurately than before with new capacitor test and storage circuit boards developed by Corning Electronic Components, Bradford, Pa. The boards are used in the reliability research and development program for the Minuteman missile guidance and control systems. The program is conducted by Autonetics, a division of North American Aviation, Inc.

Difference between the old and new boards lies in a sophisticated wiring design and use of a new material. A fiberglass-epoxy board with a two-terminal wiring design was used originally. Meaningful measurements were prevented by stray capacitance and variable insulation resistance that often masked capacitor IR.

Corning engineers worked out a three-terminal shielded circuit design and utilized the company's Fotoceram glass-ceramic. Besides the 10-to-1 improvement in capacity measuring accuracy, the combination allowed meaningful measurements down nearly to the level of capacitor IR and 0.05 per cent of dissipation factor.

An unmetallized Fotoceram upper board in each circuit board assembly carries 200 Corning fusion-sealed capacitors. Leads extend through it to a Fotoceram lower board, which carries the circuit pattern. The assembly allows rapid and repetitive measurements, convenient identification of capacitors – which are inventoried individually throughout their life – and efficient handling and shipping. After testing, Autonetics removes the lower boards and returns them to Corning for re-use. The capacitors are stored on the top boards until installed in the missile systems. Corning Electronic Components, Bradford, Pa.

Write No. 179 in Box on Inquiry Card



A. W. Haydon's portable diode tester (top) in use, and (bottom) with the cover exposed.

DIODE TESTER

Portable Unit Checks Polarity In Specified Circuit Positions

Designed to test diode matrix boards used in conjunction with 16-switch or 28-switch electronic timers, a completely portable tester consists of regulated power supplies, comparison bridge, detector, and necessary switching mounted behind a front control panel. Operating controls, indicators, and diode matrix board receptable are mounted on the front.

The manual tester checks the presence and correct polarity of diodes in specified circuit positions on the diode matrix boards. In addition, it tests the diode forward current at 1 volt and reverse leakage current at 25 volts. Those diodes meeting forward and reverse resistance specs and correct polarity in the proper place on the matrix board are so indicated by a green signal light on the front panel, while those not meeting the specs light a red signal on the panel.

Matrix board receptacles are keyed so that it is impossible to insert boards into the wrong receptacles, while visual comparison of notches in the boards to those in the tester further simplify location.

Engineers at A. W. Haydon Co., Culver City, Calif., designers of the unit, stated that the tester has also been successfully used as a megger through simple adjustment of a function selection switch. Calibration of the unit may be done by a technician without engineering supervision.

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A 32-page digest of the industry's most complete lines of single-turn and multi-turn precision pots!

With new sections on A-C . . . Non-linear . . . Liquid-filled...and Helitrim® trimming potentiometers. As well as turns-counting dials and delay lines!

Complete technical data, including environmental specs and outline drawings, is at your fingertips. And it's all arranged in a fast-reading format that makes pot picking easier.

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Helipot Division of
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Fullerton, California

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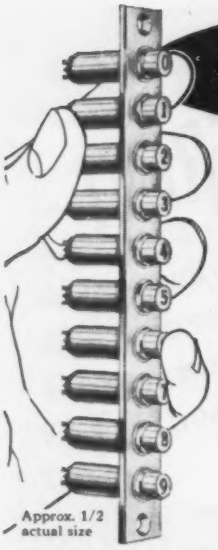

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For COMPUTERS, DATA PROCESSING, AUTOMATION, INSTRUMENTATION and MINIATURIZATION

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FOR USE AS SINGLE INDICATOR LIGHTS, OR GROUPED AS A

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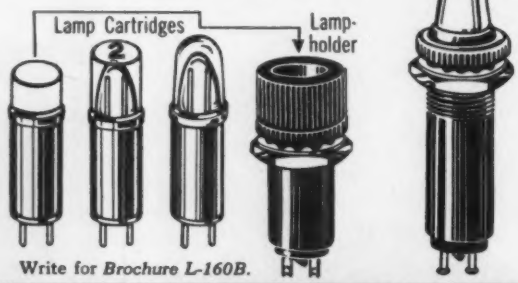
DATALITES by DIALCO are ultra-miniature Indicator Lights, made in 2 basic styles: *Lampholders* with DIALCO's own *replaceable Lamp Cartridges;* or integrated DATALITES *with Built-in Neon Lamps** ...Mount in ⅜" clearance hole... LAMPS USED: T-1¾ Incandescent; also Neon NE-2E or NE-2H.

DATA STRIP No. DSV-7538-10
Vertical ... complete with ten No. 39-28-1475 Lamp Cartridges. Other configurations to order.

Shown actual size, left to right: **Lamp Cartridges**—Nos. 39-6-1471, 38-1531, 38-931 ... **Lampholder** No. 7538 ... **Datalite** No. 249-7841-931 with built-in Neon Lamp and resistor.*



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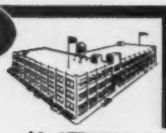
"The Eyes of Your Equipment"



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Other advantages include:
If you require a smaller capacitor with much longer life, find out about our Type LK. Designed for 4 times the life of MIL-C-25A with case sizes as much as 80% smaller.
• superior resistance
• better power factor
• withstands greater overloads
• may be operated to 125° C
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For full details, write for Bulletin LK.
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Plastic Capacitors, INC.
2620 N. Clybourn Chicago 14, Illinois DI 8-3735

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TESTING

Flutter and Wow Measurements

A sensitive meter indicates visually the wow and flutter content of all tape recorders and playback equipment. Preamplifier and input attentuator accepts voltages ranging from 1 mv to 100 v. High frequency components, 5 to 250 cycles (flutter), are measured through a high-pass filter; low frequency components, 0.5 to 6 cycles (wow), through a low-pass filter. A 3,000 cycle oscillator incorporated for recording purposes eliminates the necessity of calibrating and using external oscillators. Measurements accurate down to 0.01%. Amplifier Corp. of America, New York, N. Y.

Write No. 767 in Box on Inquiry Card

Electroexplosive Tester

No expensive field, aircraft or shipboard tests are required with a new system tester for checking resonant characteristics, and thus sensitivity of electroexplosive systems (squibs, igniters, entire missiles, explosive bolts, blasting caps, stage separation devices) to unwanted initiation. With accessories, the parameters for determining RF hazards (e.g. capacitance, Q, and inductance) can be measured also. Weight 21½ lbs. Redel, Inc., Anaheim, Calif.

Write No. 730 in Box on Inquiry Card

Time Rate Generator

Solid state timing unit generates crystal referenced timing pulses of 100, 10, 1 and 0.1 pps required by various test recording devices. Each rate is pulse width modulated; varying pulse widths allow visual detection of the different rates on the recorded output. Facilities provide for manual or automatic reset. Binary Electronics Co., Fullerton, Calif.

Write No. 734 in Box on Inquiry Card

Pulse Generator

A pulse generator compactly combined with a synchroscope generates and accurately measures rectangular voltage pulses. The pulses may be varied in width, duration, amplitude, repetition rate and polarity. Since the pulse and sweep generators receive the same triggering signal, synchronization of pulse and sweep is automatic for internally generated pulses. For externally generated pulses, controls adjust proper trigger rate for synchronization. Schaevitz Engineering, Pennsauken, N. J.

Write No. 726 in Box on Inquiry Card

WHERE SAFETY AND RELIABILITY ARE ESSENTIAL . . .

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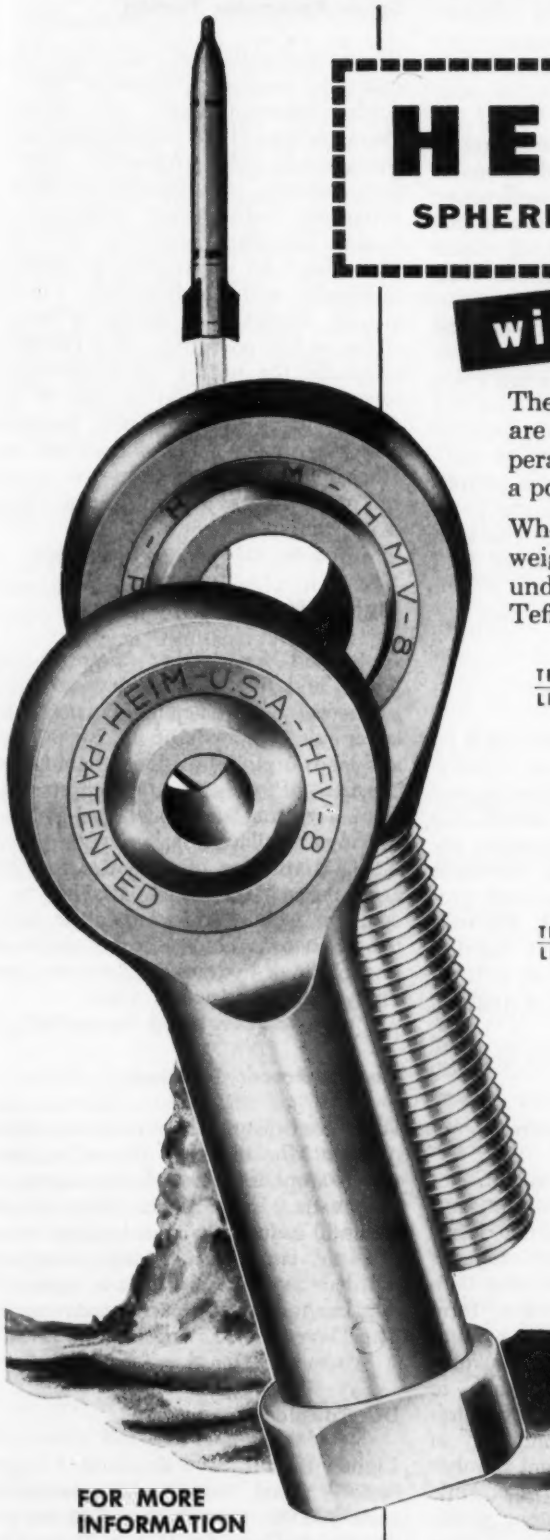
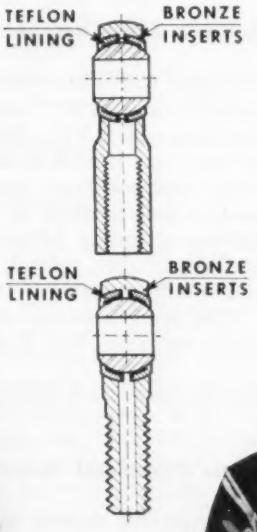
SPHERICAL BEARING ROD ENDS

with TEFLON® linings



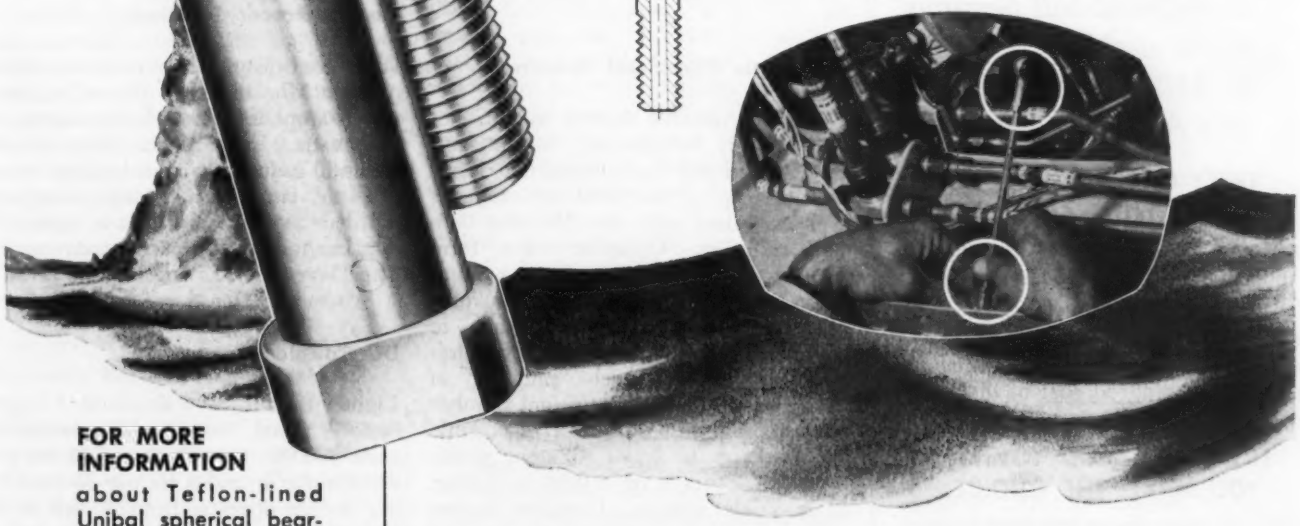
There are conditions of operation where lubricated bearings are undesirable or incapable of operation, in extreme temperatures, corrosive or humid conditions, or where there is a possibility of lubricant failure or leakage.

Where safety and reliability are essential; where space or weight savings are essential; where stick-slip operation is undesirable . . . special problems such as these are solved by Teflon-lined Unibal bearings.



Aircraft and missile manufacturers find that these fiber-lined Unibal bearings, especially for rod ends in rotor assemblies of helicopters, as well as in most other linkages, are outstanding in their performance and durability. They require no lubrication, and after hundreds of hours of service are still in perfect condition.

The Unibal Spherical Bearing Rod End corrects misalignment in all directions, has high load ratings, is light in weight, occupies minimum space, and is extremely simple to assemble as part of a linkage.



FOR MORE INFORMATION about Teflon-lined Unibal spherical bearings and the new 6-page bulletin including catalog listings of stock sizes available, write to:

THE HEIM COMPANY
FAIRFIELD, CONNECTICUT

ALL HEIM BEARINGS ARE SOLD THROUGH THE LEADING BEARINGS DISTRIBUTORS IN THE U.S.A. AND CANADA

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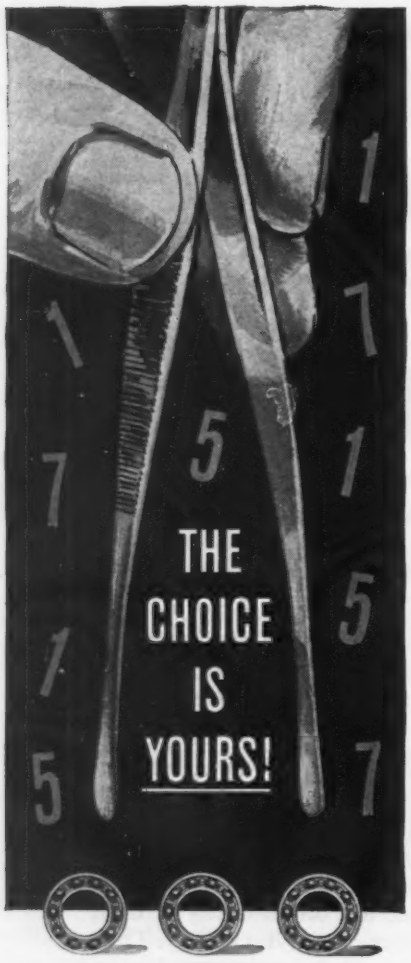


RMB

RMB miniature and instrument ball bearings are available in ABEC-1, ABEC-5 and ABEC-7 tolerances.

ONLY ONE OF THESE IS BEST FOR YOUR APPLICATION

For highly sensitive and high speed applications you'll choose the RMB ABEC-5 or -7 bearing.

For applications of less exacting requirements, you'll want to take advantage of the reduced cost of the RMB ABEC-1 bearing.

IT'S YOUR APPLICATION— YOU MAKE THE CHOICE

Find out more about the RMB line... Ask for Catalog 4E-1.

LANDIS & GYR, inc.
45 West 45th St.
New York 36, N. Y.

CIRCLE NO. 84 ON INQUIRY CARD

Lissajous Oscilloscopes

Developed initially to facilitate precise and rapid production calibration of phase angle voltmeters, an oscilloscope is applicable to most laboratory and factory testing or calibrating of phase measuring instruments and circuit components having phase shift characteristics. The scope is said to eliminate the need for critical, time consuming adjustments that are required when using general purpose scopes, thus speeding test procedures and permitting accurate use of semi-skilled personnel. In addition, the instrument's small size permits modular inclusion, either singly or in multiple, in test racks and checkout systems. North Atlantic Industries, Inc., Plainview, N. Y.

Write No. 760 in Box on Inquiry Card

Temperature Test Chamber

Test chamber, with test volume of 8 cu ft, operates from $-100°F$ to $+750°F$ with accuracies of $\pm 5°F$. Heating and cooling rates vary from 5 to 200°F/min depending upon test load. Modular design enables unit to serve in numerous applications, including laboratory, production line, quality control, life testing and plastics curing. It handles about 1000 semiconductors at a time. Statham Instruments, Inc., Los Angeles, Calif.

Write No. 768 in Box on Inquiry Card

Automatic Check-Out System

Compact, versatile testing system not only checks voltage and current, but tests modulated and unmodulated frequencies up to the 3000 mc range as well as pulses with very low rise time and duration. Complex wave form analysis is also possible from a minimum amplitude of 30 microvolts. Whenever it becomes necessary to check new characteristics, new intelligence units are merely "plugged" in quickly and easily in sufficient number for the program required. It is possible to check up to 9,999 different points with an accuracy of $\pm 0.5\%$ or better, in a single system. Complex testing of production equipment or finished products, ranging from missiles to power plant controls, can be accomplished in minutes by unskilled personnel using this equipment. Audiotronics Co., Dayton, Ohio.

Write No. 755 in Box on Inquiry Card

Servo Parameter Testing

Electro-hydraulic servo test unit automatically measures, displays and records important static and dynamic characteristics of electro-hydraulic servo components with parameters such as flow, pressure, pressure-differential, displacement, current, and frequency response, including amplitude ratio and phase lag. All measurements, both individually and combinations, can be visually displayed on meters or recorded on an X-Y coordinate plot. Designed originally for testing electro-hydraulic servovalves, it can also be used to test servo pumps, pump-motor transmissions, servovalve-actuator packages and other similar servo components. American Measurement & Control, Inc., Waltham, Mass.

Write No. 735 in Box on Inquiry Card

High RPM Dynamometer

Developed for testing motor horsepower and life to meet new stringent parameters, an efficient dynamometer is capable of speeds up to 20,000 rpm and loads up to 7 hp. The dynamometer consists of a generator constructed from a motor frame mounted on ball bearings to allow free horizontal movement. Across top of generator is a 20" arm, the end of which attaches to a common weight scale indicating inch/lbs. The test motor can be electrical, pneumatic or hydraulic. Electronic Specialty Co., Los Angeles, Calif.

Write No. 728 in Box on Inquiry Card

Testing Power Supplies

With controls for fine current adjustment, a Mho box tests power supplies, power amplifiers, etc., dissipating up to 250 watts. Each of six dials controls the total inductance thus leading to exact load currents with high accuracy. All dials set to zero result in open circuit loading for no load measurements. The Daven Co., Livingston, N. J.

Write No. 732 in Box on Inquiry Card

DC Coupled Scope

Lighter than 6 lbs, a dc coupled scope, factory wired, tested and guaranteed costs $69.95. Sensitivities: 250 mv per division for dc and 6 mv per division for ac. Sweep operates from 20 cps to 20 kc from internal or external synchronization. Horizontal input provides Lissajou patterns. Training manual included with scope is said to be able to transform a novice into an expert. Waterman Products Co., Philadelphia, Pa.

Write No. 729 in Box on Inquiry Card

Resolver Standards

A resolver standard which offers a functional accuracy of 2 seconds of arc eliminates the requirement for a null detector and a resolver transmitter mounted in an index stand. The device may be used as a reference base for resolver testing and for control systems. As a control, the resolver standard serves as a forward speed regulator for machine tools, computers, radar simulators and flight simulators. Other uses include: qualification and production testing of resolvers, production assembly testing of electromechanical assemblies, system assembly and final system testing. Astrosystems Inc., N.Y.C.

Write No. 756 in Box on Inquiry Card

Regulating Magnetic Fields

A rotating coil fluxmeter measures or controls non-uniform fields to an accuracy of 0.01%. What is said to be an exceptional accuracy has been obtained with an oscillator that stabilizes a reference magnet to one part in 10^5. The unknown field is compared to the known field by means of identical rotating coils. Motors have extremely stable speed characteristics and special slip rings and brushes to reduce contact resistance and contact noise. The fluxmeter can also be used as a field control unit to regulate magnetic fields. J. C. Carter Co., Costa Mesa, Calif.

Write No. 757 in Box on Inquiry Card

Null-Readout Oscilloscope

An oscilloscope, said to be using a null balance technique for the first time, accurately and speedily measures analog data. The 1% null-readout potentiometers measure amplitude on two signal channels as well as sweep time. An anti-parallax scale, equivalent to a mirror-backed scale on a meter, prevents errors in reading the cathode-ray tube screen. Analab Instrument Corp., Cedar Grove, N. J.

Write No. 727 in Box on Inquiry Card

Dynamic Rectifier Analyzer

Self-contained analyzer tests semiconductor rectifiers at any combination of ratings from 100 ma to 20 amps and from 0 to 1000 volts under actual operating conditions. It also evaluates heat sink design. Suited for incoming and on-line inspection and laboratory use the analyzer exceeds test conditions of proposed JEDEC specs. Wallson Assoc., Inc., Elizabeth, N. J.

Write No. 733 in Box on Inquiry Card

Gear Analyzer

Versatile gear analyzer enables visual observation of shaft backlash angle and detection of minute shaft motion while determining breakaway torque. Glowing lights indicate the attainment of desired torques which preset to any value from 0.002 to 48 oz-in. No external voltage regulation required. Rotiform Co., Santa Monica, Calif.

Write No. 731 in Box on Inquiry Card

Decal Measures Vibration

An optical decal, easily affixed to shake table, fixture or test specimen in proximity to a vibration pickup, achieves ±5% accuracy in vibration measurements which require only the naked eye and a simple light source. The mylar decal simplifies spot checking the calibration of vibration measuring systems during environmental vibration tests. It indicates visually vibratory motion of 0.085", double amplitude. Kit of five decals with instructions: $1.75 plus postage. Wrisley Engineering, Inc., Winchester, Mass.

Write No. 769 in Box on Inquiry Card

WORTH FILING

Vibration Control

16 page catalog contains principles of vibration testing along with descriptions of, and specs for: electrodynamic exciters (max force output: 1.2 to 100,000 lbs); electrohydraulic shaker systems; electronic power supplies (output tube plate dissipation: 2 to 240 kw max); and sine and random motion electronic control consoles. Sections also treat: vibration pickups and vibration meters used in testing engines and other equipment subject to vibration; vibration isolating Isomode pad and engine, machinery and shipping container mounts.

Source: Textron Electronics, Inc.
New Haven, Conn.

For Your Copy: Write No. 805 on Inquiry Card

Fluorescent Compounds

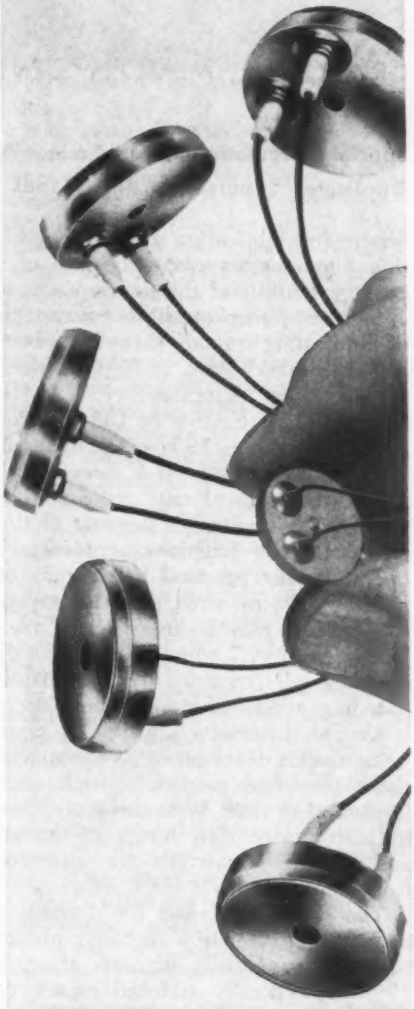
As a guide to identifying solutions through their fluorescent properties, a 19-page booklet lists characteristics of several hundred fluorescent compounds. Also included are activation and fluorescing wavelengths, pH values, and ultimate sensitivities. A bibliography of about 40 fluorometry papers describes a wide range of research projects.

Source: American Instrument Co., Inc.
Silver Spring, Md.

For Your Copy: Write No. 847 on Inquiry Card

NEED HEAT?

Up to 20 watts in ¾" diameter with Minco's H4A Button-Heater.



- Metal case, center-screw mounted, weighs less than 4 grams.
- Operates to 500° F. internal temperature.
- 2, 5, 10, 15, or 20 watt models at 115 volts.
- Simplified thermal engineering method described in data sheet.
- Initial shipment made within 24 hours when requested.
- $10 each for 1 or 2, $8.50 each for 3-10, $7.20 each for 11-25.

FREE PRODUCT FOLDER OF THERMAL-DEVICES

Request EEM-5300 file for technical data about Heaters, Thermal-Ribbons, Thermal-Indicator, Resistance Temperature Detectors, and Precision Resistance Thermometers.

MINCO PRODUCTS, INC.

740 Washington Ave. No.
Minneapolis 1, Minnesota
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CIRCLE NO. 6 ON INQUIRY CARD

TECHNIQUES

CRYOGENIC MEMORY DEVICES

Special Automatic Process Accurately Duplicates Superconducting Planes

Successful fabrication of a cryogenic thin film memory plane the size of a postage stamp and the development of automatic control techniques capable of duplicating it many times have been achieved by scientists at IBM's Federal Systems Div., Kingston, N. Y. The memory plane consists of 135 cryotron devices built up in 19 layers of material.

Three cryotrons form a memory cell which combines storage with an elementary logic pattern. Because of this combination of functions, sophisticated operations not practical before may be realized. For example, scientists expect this concept may be used in an "associative memory," which simultaneously searches all memory compartments, speeding access to stored information.

Key to this major advance in cryogenic device development is the special technique which permits accurate duplication of devices With this technique, microscopically thin layers of metals and insulating materials are automatically deposited on a glass substrate.

The equipment used for deposition allows each layer of a metal or insulator to be sequentially deposited through 17 microscopically adjusted masks, or perforated metal sheets. The masks are changed automatically like records in a juke box and are held in a large metal cylinder operating under high vacuum. Once the masks have been properly aligned, the process automatically produces duplicate superconducting memory planes with similar electrical and mechanical characteristics.

Forty separate pieces or "bits" of information are stored in 120 cryotrons. Of the remaining 15 cryotrons, 10 permit access to the stored bits of information; the other five are "in-line" cryotrons which switch bits of information from one memory plane to another. These newer "in-line" cryotrons operate faster than conventional cryotrons in communicating between the memory planes. They also permit faster communication between memory planes and arithmetic portions of a computer.

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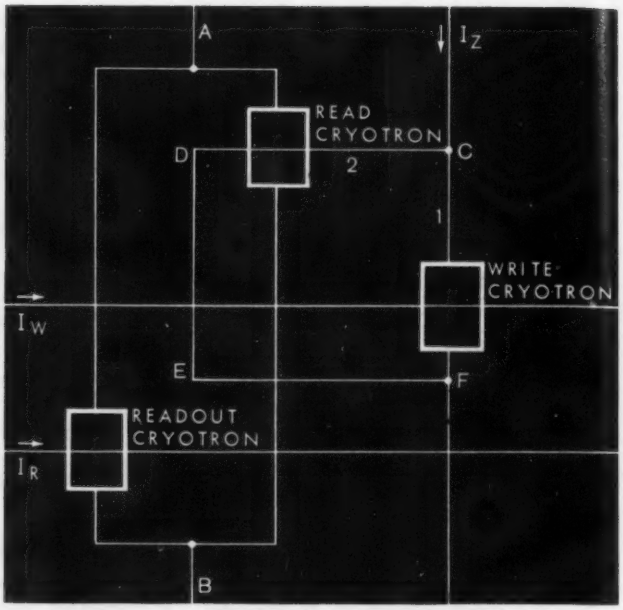

Fig 1 Schematic diagram of memory cell. The thin-film 135 cryotron memory plane relies on a basic building block of three crossed-film cryotrons in combination with a persistent current loop to make up a storage cell. A persistent current is set in the loop CDEFC if the following operating-sequence is followed: (1) apply Iw to the WRITE cryotron to hold the WRITE gate normal (2) apply information current Iz which will now have to go through Branch 2 of the persistent current loop. (3) Remove Iw. The information current Iz now remains in Branch 2 of the persistent current loop, even though the WRITE gate is now superconductive; (4) remove information current Iz. The persistent current is destroyed in the loop by the application of Iw, causing the WRITE cryotron to become resistive, while the information current Iz is zero in magnitude. The presence or absence of a persistent current can be detected by monitoring the resistance between points A and B while current Ir is applied, thus causing the READ-OUT cryotron to be resistive. When a persistent current is not stored, the READ cryotron is superconductive and there is no resistance between points A and B.

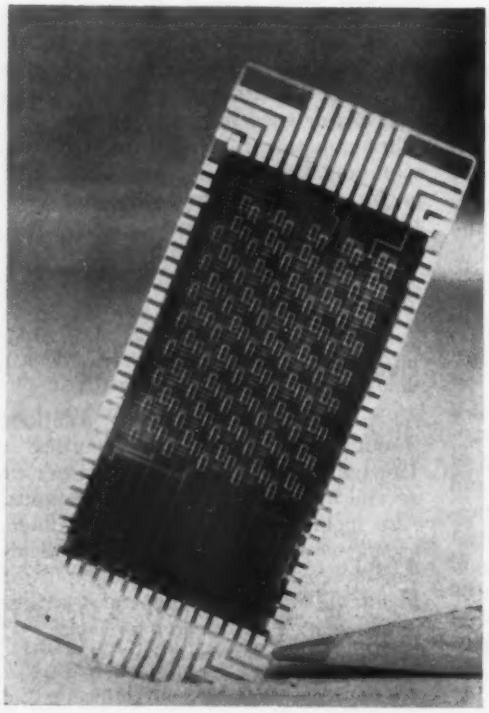

Fig 2 Experimental cryogenic memory is a word-oriented (2-dimensional) plane consisting of 8 word-registers with 5 bits per word, given a total of 40 memory cells. Word-register selection is accomplished with room-temperature equipment. The 135-cryotron thin film planes are fabricated in a 36″ x 36″ horizontally mounted stainless steel cylindrical vacuum tank. Each plane requires only one pump-down of the vacuum system; all evaporations occur at pressures approximating 10^{-7} mm Hg. Film thicknesses are automatically controlled by a rate-monitor which controls the rate of film deposition during a specific time interval. Completed planes are fastened mechanically and electrically to a sample holder and are then placed in the liquid helium environment for testing.

PRINTED CIRCUIT CARDS

"Universal" Design Speeds Production of Short-Run Equipment

Standardization and prefabrication of components and subassemblies which can be used in more than one special model of a computer is generally believed to be an impossible concept according to Librascope, Inc., Glendale, Calif.

Librascope engineers' approach to the problem was to make careful and analytical study of the basic design parameters of each class of computer to determine the general circuitry needed. On the stock cards developed from this study, components may be added to form logic modules before the final design of the computer is ready, and then, when the design is firmed, these modules may be interconnected to form the required circuits.

In producing the universal printed circuit cards for various types of computers, Librascope divides the assembly into two steps. The first is a preassembly, at which point all cards destined for a specific class of computer look alike. This preassembly stage takes place before the logical design of the computer has been completed, permitting the industrial engineering dept. to perform a large amount of fabrication prior to full production.

The second phase involves working out the interconnections of the individual modules to provide the proper circuits for the computer after the computer design has been completed.

Developed to speed production of extremely short run equipment, the technique does not result in the most compact packaging or in a card that is particularly adaptable to mass production. When a single unit or less than five machines are being built, savings in production time and reduction in the lag between design and assembly makes this technique highly desirable.

Etched circuitry is carried through from the base plug to the top of each card where a duplicate connector is provided, permitting cards to be connected to test instruments while plugged into computer.

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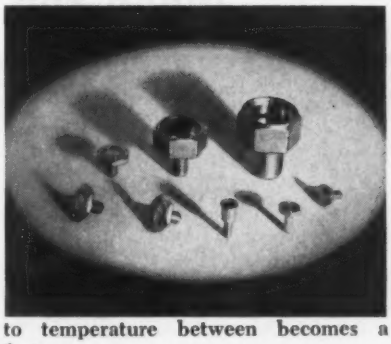
SEMICONDUCTOR MOUNTING BASES

Cold forming two superior alloys results in improved thermal and electrical conductivity.



Most stud-type heat sink bases have been made of tellurium copper since it could be readily machined. According to Standard Pressed Steel Co., Jenkintown, Pa., the more desirable material, oxygen-free copper, previously was bypassed because of the near impossibility to machine it into the complex shapes required by semiconductor mounts. This material also defied early attempts to cold form it successfully.

A new SPS cold forming process completely tames the high conductivity, oxygen-free copper and also permits it to be satisfactorily machined—should this be desired—as a subsequent operation. The company reports that the new oxygen-free, cold forged copper bases provide as much as 10 percent more electrical and thermal conductivity than tellurium copper.

Use of another copper alloy—a zirconium copper containing 0.15 zirconium—produces a high-strength series of bases, which retain high strengths even after exposures to temperatures of 1000 F at which materials generally in use are annealed. This is an important consideration since brazing and welding are presently among the favored methods for joining the bases and mating caps in the final assembly of semiconductors. The zirconium-copper alloy produces parts with much greater torque-strength ratings. As a result of alloying ingredients and the special SPS processing, the strength of these zirconium-copper bases actually increases slightly after exposure to temperatures up to 1000 degrees. Beyond that point, considerable initial strength is still retained, but length of exposure to temperature between becomes a factor.

With both oxygen-free zirconium-copper bases, a closer control over functional dimensions stems from the inherent accuracy of the precision cold forging process. Accuracy is built into the forging dies and close tolerances can be held over relatively long production runs. Closer control over one of the critical dimensions—the squareness of base bottom to mounting thread—provides an added measure of heat and thermal conductivity for either type material. Any angularity at this point tends to reduce contact between base bottom and chassis, thus reducing the degree of electrical and heat conductivity. Closer control over flatness of the top of the bases facilitates mounting of the semiconductor and the hermetic sealing of the final assembly. Basic economy of the cold forming process in substantial runs is said to offset the added cost of both the higher priced zirconium and oxygen-free materials.

SPS currently is producing threaded and non-threaded bases of both new materials in the most widely used 7/16 and 11/16 inch sizes (the across flats dimension of the hexagon base.) The company also makes parts ranging in size from miniatures to 1¼ inches across the flats and they believe that larger sizes should be equally feasible. A variety of special configurations has been made to order.

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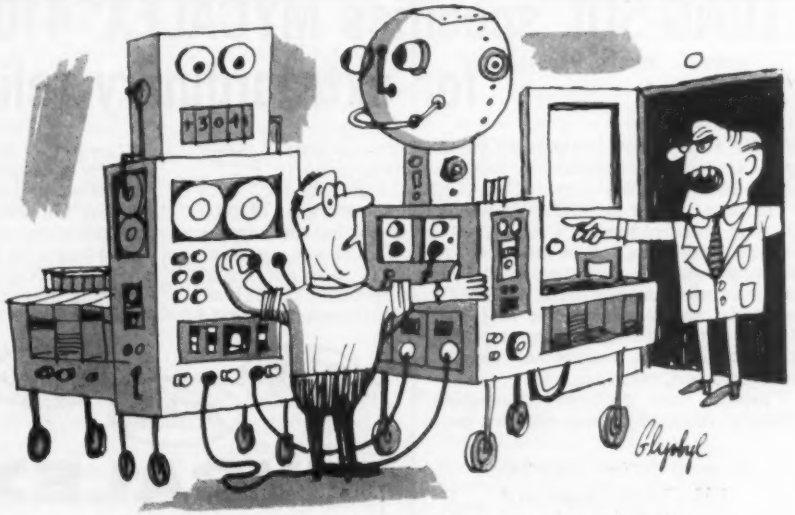

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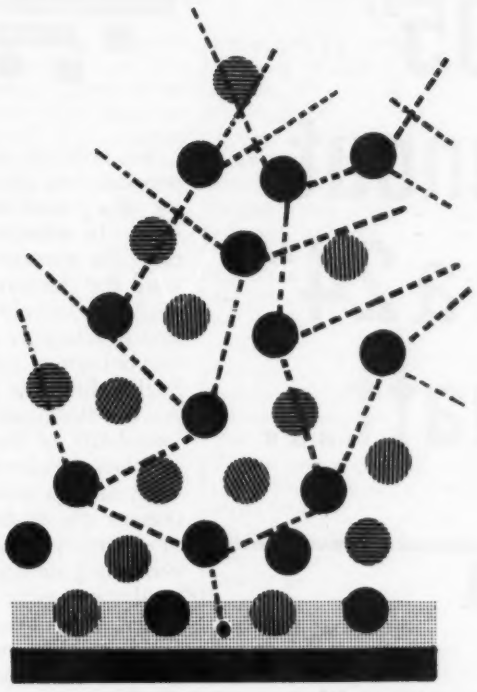

COMPONENTS DIGEST 14

Electrical Insulation, Part 2

Part I of this Digest appeared in the May 1960 Issue. The purpose of the Digest, as stated there, is to help the electromechanical designer solve insulation problems in advanced applications where insulation systems are required to work reliably in extremely compact packages under a wide range of environmental conditions. We pointed out that choosing the best insulation for a given job is a very difficult task. The list of available types in every class is enormous. We therefore avoided classifying commercially available insulations, concentrating on description of insulation characteristics, design and selection factors, and methods of test. Our aim was to acquint the project engineer with fundamentals which permit him to read about and discuss insulations with understanding.

In the last section of Part I we reviewed papers presented at the Second Annual National Conference on the Application of Electrical Insulation – 1959 that were of particular interest to electromechanical engineers. Part II, presented here, brings the Digest up to date by summarizing similar information from the Third Annual Conference on the Application of Electrical Insulation held in Chicago, Dec., 1960.

Types of Chemical Bonds

The design engineer who attempts to understand the behavior of electrical insulating materials as a means for more rational selection for specific applications may run into problems. The past two decades of research by chemists and physicists have tended to emphasize the molecular and atomic structure of materials and their relationship to the performance of materials under various environmental conditions. Thus, yesterday's understanding of the presence or absence of conducting phenomena within a material based on electron mobility and electron conduction (see Fig. 1) is not enough. Chemists have come up with additional phenomena that aid in clarifying or clouding our understanding depending on the extent to which their explanations and language make sense or nonsense.

Perhaps one of the clearest explanations associated with the types of chemical bonds and their influence on the passage or restriction of electrons through materials was presented by Jack Swiss of Westinghouse Electric Corp. His discussion of ionic, covalent, and polar bonds makes sense to us.

IONIC BONDS

Elements in the group at the left of the Periodic Table have a strong tendency to form a stable outer electron shell by losing their valence electrons. In this process, they become positive ions and such elements are said to be electropositive. In any one group, this tendency to lose valence electrons becomes stronger as the atomic radius increases, thereby decreasing the force of attraction between the nucleus and the outermost electrons. For example, sodium, with an atomic radius of 0.95 Angstrom is much more electropositive than hydrogen, whose atomic radius is about 0.3 Angstrom.

On the other hand, the elements at the right of the Periodic Table have a strong tendency to form a stable outer electron shell by completing their nearly filled octet. In this process, they become negative ions and these elements are said to be electronegative.

Recognized Major Causes of Insulation Failure

Thermal aging as determined by cumulative time-temperature effects.
Moisture absorbed into the solid insulation and accumulated on the insulating creepage surfaces.
Conducting contaminants resulting from combinations of dirt, chemicals, oils, etc.
Differential expansion and contraction of conductors, magnetic structure, and insulation (more pronounced on large machines with long cores).
Mechanical damage from short circuit stress, physical shock, vibration, or loose foreign objects.
Corona (low energy) or slot discharge (high energy).
Surge voltage phenomena.
Operation at abnormal voltages.
Operation at abnormal currents.
Loosened coils and wedges due to shrinkage.
Loss of end winding support.

Less than .005" Runout on a 24" Shaft...

Holtzer-Cabot Solves Fractional H.P. Motor Problems

Holding runout tolerances on a motor shaft extending 24" beyond the motor frame poses a difficult design problem. To reduce runout, many manufacturers have resorted to complicated and expensive outboard bearings and shaft supports. To avoid this problem, one such company* came to Holtzer-Cabot, which in cooperation with the company's engineers, developed a motor with a special extended end cap and a heavier shaft. The result: less than .005 runout at one inch from the end of the 24" shaft.

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COMPONENTS DIGEST

An ordinary single chemical bond between two atoms is believed to consist of a pair of electrons with opposite spins. In substances like sodium chloride, the electron pair is displaced toward the chlorine atom, so that the sodium is relatively positive and the chlorine is relatively negative. The resulting linkage is called an "ionic" bond. Such substances in the dry solid state are excellent insulators because of the immobility of the ions. When molten, or when dissolved in a dissociating solvent, such as water however, such substances are relatively good conductors of electricity. Some insoluble substances containing similar ionic bonds are good insulators, even in the presence of water, their insolubility and resulting ion immobility making conduction impossible. Mica is an example of such a substance.

COVALENT BONDS

Elements in the central part of the Periodic Table are neither strongly electropositive nor strongly electronegative and for this reason tend to share the electron pair more or less equally between the two atoms being joined. This type of bond, a "covalent" or shared electron pair bond, has essentially no tendency to dissociate to form ions or free electrons, and substances containing only covalent bonds are excellent electrical insulators. Furthermore, such substances have little tendency to absorb or dissolve ionic conducting materials. The property of forming covalent bonds is most pronounced in the element carbon and for this reason the number of compounds of carbon far outnumbers the compounds of all other elements combined. Compounds containing carbon are called "organic" compounds.

POLAR BONDS

Still another type of bond which must be considered, is one in which the electron pair displacement is intermediate between that present in ionic bonds and that present in covalent bonds. The hydrogen chloride molecule, for example, is similar to sodium chloride with this difference: The hydrogen electron is held more strongly to the hydrogen atom because the atomic radius of hydrogen is about one-third that of sodium; as a result; the electron pair is displaced toward the chlorine, but not as far as in sodium chloride where it

Check List of Important Properties In Selecting Insulating Materials

Though all of the following properties are not necessarily applicable to any one specific insulation problem, a check of the list will aid you to select those properties that should be considered. It is important to keep in mind the effects of temperature upon the properties and to evaluate an insulating material with respect to the conditions it will meet in service.

ELECTRICAL

- Volume resistance
- Volume resistivity
- Surface resistance
- Surface resistivity
- Dielectric constant
- Dielectric break down strength
- Dissipation factor
- Loss factor
- Power factor
- Phase angle
- Loss angle
- Arc resistance
- Corona resistance
- Tracking resistance
- Permittivity

MECHANICAL

- Ultimate tensile strength
- Ultimate compressive strength
- Shear stress (direct)
- Shear stress (bending)
- Flexure strength
- Modulus of elasticity
- Modulus of rupture
- Impact strength (Izod — cantilever)
- Impact strength (charpy — notched beam)
- Hardness (indentation at room & elevated temp)
- Tear strength
- Percent elongation
- Flexibility
- Machinability
- Fatigue stress (simple & combined stress)
- Abrasion resistance
- Stress crazing
- Specific gravity
- Refractive index
- Transparency
- Color
- Porosity
- Permeability to gases
- Moisture absorption
- Thermal conductivity
- Thermal expansion
- Creep (threshold at room & elevated temp)
- Plastic flow
- Thermal decomposition
- Spark & flame resistance
- Melting point
- Pour point

CHEMICAL PROPERTIES

- Resistance to reagents
- Effects upon adjacent materials
- Electro-chemical stability
- Stability against ageing
- Stability against oxidation
- Solvent crazing
- Resistance to light
- Resistance to moisture
- Solubility
- Resistance to fungus

essentially is transferred to the chlorine. The bond in hydrogen chloride is called a "polar" bond.

Such a bond has both covalent and ionic characteristics. Because the electron pair is not symmetrically placed, one atom of the molecule becomes relatively negative and the other relatively positive. Such a molecule tends to rotate in an electric field, and this movement of charge constitutes conduction under some circumstances. Materials that have a large number of polar bonded atoms or groups, able to rotate rapidly, have a high dielectric constant. The increase in dielectric constant over that of nonpolar molecules is roughly proportional to the concentration of dipoles and to the square of the magnitude of each. The mixture of chlorinated biphenyls, having a dielectric constant of about 6, which is widely used as a capacitor dielectric, owes its high dielectric constant to the presence of the unsymmetrically oriented polar carbon-chlorine bonds.

Failure and Breakdown Values

Graham Lee Moses of Westinghouse Electric Corp. believes that electrical insulation can be said to be a state of matter rather than a class of materials since all insulating materials are characterized by a scarcity of free electrons in the physical structure. In his paper mistitled "The Purpose of Electrical Insulation" Mr. Moses presented an excellent analysis of the various failure theories associated with insulation material and emphasized a point not too clearly understood or appreciated by the average engineer who is only occasionally involved in the selection of an insulation material for a specific application.

More often than not, the average engineer who needs a material for a specific application tends to be guided in his choice on what has been used before for similar applications. Today's trend is to express your need for a specific material in terms of the properties you desire. However, properties of engineering materials, as Mr. Moses points out, can be discussed from two different points of view: failure values and withstand values. In the case of dielectric strength of insulation a failure value is a voltage at which the material fails and is usually stated as the average failure voltage determined by a number of tests. The withstand value is an expression of the voltage an insulation can withstand and is often stated as a minimum voltage at which or below which no failure may be expected. Fail-

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ELECTRICAL PROPERTIES RELATING TO INSULATION RESISTANCE

Dielectric Constant—The dielectric constant, K, of an insulating material is the ratio of the parallel capacitance of a given configuration of electrodes with the material as the dielectric to the capacitance of the same electrode configuration with a vacuum as the dielectric. Capacitance, C, of a capacitor is the ratio of the charge which can be stored in the capacitor to the potential applied to it. It is expressed in farads when the charge is expressed in coulombs and the potential in volts. Insulating materials are used in general in two distinct ways, (1) to insulate and support components of an electrical network from each other and from ground, and (2) to function as the dielectric of a capacitor. For the first use, it is generally desirable to have the capacitance of the support as small as possible, consistent with acceptable mechanical, chemical, and heat-resisting properties. A low value of dielectric constant is usually desirable, so that the capacitor may be physically as small as possible. Intermediate values of dielectric constant are frequently used for grading stresses at the edge or end of a conductor to minimize corona.

Series Representation—While the parallel representation of an insulating material having a dielectric loss is fundamental, it is always possible and occasionally desirable to represent a capacitor at a single frequency by a capacitance, C_S, in series with a resistance, R_S. The dissipation factor, D, of the capacitor is the same for both the series and parallel circuits as follows:

$$D = R_S\omega C_S = 1/R_p\omega C_p$$

The relations between series and parallel components are as follows:

$$C_S/C_p = 1+D^2$$

$$R_p/R_S = (1+D^2)/D^2 = 1+1/D^2 = 1 + Q^2$$

Note: the series capacitance is larger than the parallel capacitance by less than 1 percent for a dissipation factor of 0.1, and by less than 0.1 percent for a dissipation factor of 0.03.

If the measuring circuit yields results in terms of series components, the parallel capacitance must be calculated before determining the dielectric constant.

Dissipation Factor—The dissipation factor of an insulating material is the ratio of the conductance, G, of a capacitor in which the material is the dielectric to its susceptance, B, or the ratio of its parallel reactance, X_p, to its parallel resistance, R_p. It is also the tangent of the loss angle, tan δ (also called loss tangent), and the cotangent of the phase angle, cot θ. It is represented by the symbol D:

$$D = \cot\theta = \tan\delta = G/B = X_p/R_p = G/\omega C_p = 1/R_p\omega C_p$$

where:

$\omega = 2\pi$ times the frequency in cycles per second.

The reciprocal of the dissipation factor, D, is the storage factor, Q, sometimes called the quality factor.

Loss Factor—The loss factor, DK, of an insulating material is equal to the product of its dissipation factor, D, and dielectric constant, K. It is proportional to the energy loss per cycle per squared potential gradient per unit volume.

Power Factor—The power factor of an insulating material is the ratio of the power in watts dissipated in a capacitor in which the material is the dielectric to the product of the sinusoidal voltage and current expressed in effective volt-amperes. It is also the cosine of the phase angle of the material, cos θ, and the sine of the loss angle, sine δ. It is usually represented by the symbol PF.

Note: when the dissipation factor is less than 0.1, the power factor is smaller than the dissipation factor by less than 0.5 per cent. Their exact relationship may be found either by reference to trigonometric tables or from the following relations:

$$PF = D/(1+D^2)^{1/2}$$

$$D = PF/[1-(PF)^2]^{1/2}$$

Phase Angle—The phase angle of an insulating material is the angle by which the current in a capacitor, in which the material is the dielectric, leads the voltage across it, both current and voltage having the same frequency. It is represented by the symbol θ.

Loss Angle—The loss angle of an insulating material is the complement of its phase angle. It is represented by the symbol δ. It is sometimes called the phase defect angle.

Power Loss—For both cases (as electrical insulation and as capacitor dielectric) the power loss generally should be small, both in order to reduce the heating of the material and to minimize its effect on the rest of the network. A low value of loss factor, at high frequencies is desirable because, for a given value of loss factor, the power loss increases directly with frequency. In certain dielectric configurations such as are used in bushings and cables, an increased loss, usually obtained from increased conductivity, is sometimes introduced to control the voltage gradient in the insulation. In comparisons of materials having approximately the same dielectric constant, the quantity considered may also be dissipation factor, power factor, phase angle, or loss angle.

Insulation Resistance—The insulation resistance between two electrodes which are in contact with, or embedded in, a specimen is the ratio of the direct voltage applied to the electrodes to the total current between them. It is dependent upon both the volume and surface resistances. Insulating materials are used in general to insulate and support components of an electric network from each other and from ground. For this purpose it is generally desirable to have the insulation resistance as high as possible, consistent with acceptable mechanical, chemical, and heat-resisting properties, although in many cases it need be only high enough to have no appreciable effect on the operation of the network. Since insulation resistance combines both volume and surface resistance, its measured value is strictly applicable only when the test specimen has the same form as is required in actual use.

Volume Resistance—The volume resistance between two electrodes which are in contact with, or embedded in, a specimen is the ratio of the direct voltage applied to the electrodes to that portion of the current between them that it distributed through the volume of the specimen.

Surface Resistance—The surface resistance between two electrodes which are on the surface of a specimen is the ratio of the direct voltage applied to the electrodes to that portion of the current between them which is in a thin layer of moisture or other semiconducting material that may be deposited on the surface.

Volume Resistivity—The volume resistivity of a material is the ratio of the potential gradient parallel to the current in the material to the current density.

Surface Resistivity—The surface resistivity of a material is the ratio of the potential gradient parallel to the current along its surface to the current per unit width of surface.

Note: surface resistivity of a material is numerically equal to the surface resistance between two electrodes forming opposite sides of a square. The size of the square is immaterial. When the volume and surface resistivities of an insulating material have been determined, it becomes possible to design an insulator for a specific application. The changes of both resistivities with temperature and humidity may be great, and must be known in order to meet operating conditions. Surface resistivity changes very rapidly with humidity, while volume resistivity changes only slowly, although the final change may be greater. Volume and surface resistivity measurements are often used in checking the uniformity of an insulating material, either to determine the uniformity of processing or to detect traces of impurities which affect the quality of the material and which may not be readily detectable by other methods.

Correlation — When adequate correlating data are available, resistance or resistivity may be used to indicate the suitability of a material in other respects, such as dielectric breakdown, dissipation factor, moisture content, degree of cure, mechanical continuity, and deterioration from whatever cause. While the actual value of resistance or resistivity may be important initially for any material, it is the change in resistance or resistivity that is significant when there is a change in the material. The insulation resistance test is of greatest value when the test specimen has the same form as that required in actual use.

When adequate correlating data are available, dissipation factor or power factor may be used to indicate the suitability of a material in other respects, such as dielectric breakdown, moisture content, degree of cure, and deterioration from whatever cause. While the actual value of dissipation factor is important initially for any material, it is the change in dissipation factor that is significant when there is a change in the material.

ure values are a statement of test data whereas withstand values are a conservative interpretation of the ability of the insulation to successfully withstand specific conditions.

More than that the values quoted will depend considerably on the type of test used. Thus when an insulator is subjected to a voltage sufficiently high to produce rupture, the voltage at which such breakdown occurs is defined as the electric breakdown strength. This strength depends on a number of factors including the rate of voltage rise, the time of voltage application, the frequency of the voltage applied, atmospheric conditions, thickness of the insulation specimen, temperature and electrode configuration. For these reasons, Mr. Moses emphasizes, standard test procedures must be employed. The duration of the application of the test to the specimen is of great importance since most insulations vary widely in the voltage required to produce breakdown depending on the duration of the dielectric stress. Few common dielectric tests are in use. One is the rapid-rise short-time test wherein the voltage is raised at a constant rate. The other is the step by step test where each successive voltage is applied for a specific length of time (usually one minute) until failure occurs.

Here is a summary of the various breakdown theories Mr. Moses presented.

SOLID INSULATION DIELECTRIC BREAKDOWN THEORIES

Thermal Theory. The thermal theory of breakdown is based on the belief that all solid dielectrics are heterogeneous and variable. Therefore, some parts or areas of a dielectric have lower resistance than other parts of an apparently uniform material. Thus, the current within a given insulation sample is not uniformly distributed. Weak parts carry more current and are heated more than other parts. If the heat is not removed as rapidly as it is generated in any part of the dielectric, the weaker spot grows hotter and its resistance becomes lower, because insulations decrease in resistance as their temperature increases. The temperature continues to rise as the voltage is increased until thermal instability occurs. This is quickly followed by breakdown of the insulation at its weakest point.

Ionic Theory. Another theory is based on the assumption that a solid dielectric acts as an electrolyte and ions move within it to produce current flow. Such ionization may be from either collision or chemical action under the influence of the field voltage.

Disruptive Theory. According to this theory, electric breakdown of insula-

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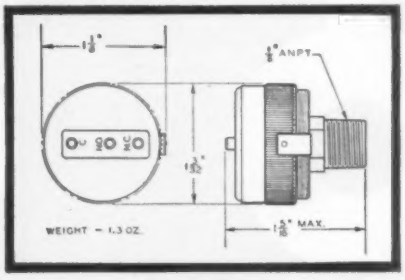


Dimensions

BRISTOL FINE PRECISION INSTRUMENTS FOR OVER SEVENTY YEARS

CIRCLE NO. 35 ON INQUIRY CARD

tion is the effect of physical rupture within the solid, resulting in destruction of molecular and other bonds in the dielectric.

AIR BREAKDOWN

The electrical breakdown of air is accompanied by a luminous discharge usually followed by a sparkover when the air between electrodes is ionized. All gaseous dielectric breakdown is of this general nature, but air is the one of most interest to electric equipment designers. Prior to the sparkover, there usually is a small, dark discharge current through the gas which can only be detected in a darkened room or with very sensitive instruments. Gaseous breakdown occurs upon the application of sufficient voltage to free electrons in the field so that they move across the gap and multiply by collision with gaseous molecules. Gaseous breakdown is a fairly reproducible phenomenon, particularly between plane or spherical electrodes.

SOLID INSULATION BREAKDOWN

Solid insulations are of greatest importance because they provide a dielectric barrier effect which furnishes far greater and more reliable protection than air spacing or creepage separation. Low voltage apparatus may rely upon air spacing; and high voltage apparatus where space is of no consideration, may also rely upon air for major insulation. However, at the intermediate voltages, particularly where windings and magnetic core are closely coupled, it is of the utmost importance that a dielectric barrier insulation be used. In all apparently solid insulations, the barrier must be effectively solid and nonporous Good dielectric barriers may have ten or more times the dielectric strength of air spacing. Furthermore, this barrier insulation level is usually reliably maintained under adverse conditions of moisture and dirt. Solid dielectric barriers obtain their high dielectric strength by the nature of the component materials and the manner in which they are fabricated.

VOLTAGE ENDURANCE

Solid insulation will break down at different voltages depending on the duration of voltage application. Thus, any statement concerning dielectric strength about a particular material is meaningless unless it specifies or implies the time of voltage application just prior to breakdown. Standardized tests, such as ASTM, specify this so that reference to a specific test establishes the time factor. In the last several years, many voltage endurance tests have been made on different materials on a statistical basis. These tests range from less than a microsecond up to more than a year's duration. This work has demonstrated that, over the whole range studied, the breakdown voltage continues to diminish if the duration of the test is extended.

SPACING AND CREEPAGE

Many electrical devices or circuits within a device do not require solid barrier insulation for design or voltage reasons. Space may be enough to separate the conductors across an insulating surface or through a porous insulation, particularly when the voltage is relatively low. Here, it is essential to recognize that there is a threshold of voltage required to break down any gas spacing. Thus, for a few volts, any separation between two wires is adequate as long as it is cleaned and dry. For very small spacings between conductors, the insulation level is approximately equal to the air breakdown of that spacing. Where conductors are separated across an insulating surface,

the breakdown may be below that of the insulating value of the gas spacing because of field distortion and conduction over the surface. It should be recognized that humidity and dirt will seriously reduce the breakdown level through porous insulation or over a creepage surface.

ELECTRIC STRESS DISTORTION ON DISSIMILAR INSULATIONS

Two different insulating materials must be given special consideration when they are used in series as their dielectric strength cannot be added without considering voltage distribution. Since the most usual case is where a solid insulation is in series with air or some other gas, the greatest stress is transferred to the gas because of its lower dielectric constant. The gas will then break down first, transferring full voltage to the solid insulation.

MOISTURE EFFECTS ON INSULATION

Insulation is seriously affected by both moisture and humidity. Moisture is absorbed into the pores of solid insulation thereby reducing its insulation resistance and increasing its power factor. When moisture wets an insulation surface, a thin film of water may be formed rendering the surface highly conductive.

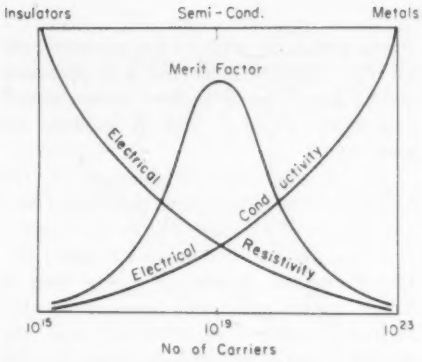
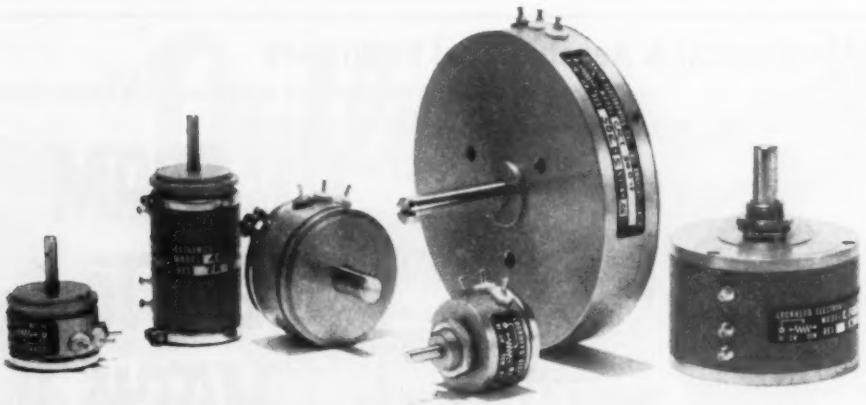


Fig 1. Conducting properties as a function of number of carriers. Physicists define the electrical insulating qualities of a material in terms of the number of carriers present per unit volume of matter. Insulators have been defined as materials that have not more than 10^{15} carriers per unit volume; conductors, materials that have 10^{21} carriers or more; and semiconductors, materials that have an intermediate number, 10^{19} carriers. The number of carriers present in the material is a rough measure of the ease with which electrons can be transported or moved through a given material. In insulators conductivity generally increases with increase in temperature. The negative temperature coefficient of resistivity is explained on the basis that the number of "holes" increases because the greater amplitude of vibration at higher temperatures increases the probability of their occurring. Also, mobility decreases because the ions absorb enough energy to jump into the "holes."

When distributed throughout the solid form of an insulation, water produces significant increase in capacitance and power factor together with a serious reduction in insulation resistivity. The rate and extent to which moisture will be absorbed into insulation, and thus affect its insulating characteristics, depend upon the relative humidity of the surrounding air and upon the frequency of the voltage at which tests are made on the insulation. The rate of moisture absorption and the degree of retention of moisture depend upon the porosity of the material. When exposed to saturated atmospheres and tested at power frequencies, the insulation capacitance may double and the power factor may approach 100%. Under such conditions, the insulation resistance may be reduced by a factor as much as one million to one. Surface films of moisture may form, particularly when the insulation is exposed to temperature changes and high atmospheric humidity conditions, resulting in dew.

Class-F Insulations

In recent years interest in Class-F (155°C) insulation systems has grown markedly. Much work is currently going on in developing and evaluating Class-F materials. Although future standards are in the process of being



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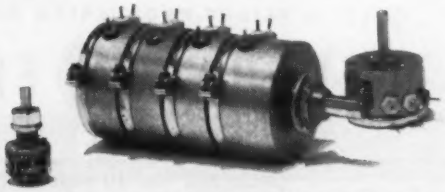

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CIRCLE NO. 26 ON INQUIRY CARD

COMPONENTS DIGEST

compiled, eventual demand for Class-F systems is uncertain. In a paper titled "Review of Class-F Insulating Systems," E. W. Summers of Westinghouse Electric points out that one reason for this uncertainity is lack of standardization of Class-F systems with respect to evaluation and proof of suitability. In the absence of standard tests, individual tests performed by insulation manufacturers must be relied upon, together with the accumulation of actual field experience of a period of years. In effect, the integrity of the supplier must be relied upon to determine whether his material or system qualifies for Class-F application.

Summers contends that a more serious problem facing Class-F systems is the lack of knowledge of where Class-F ac motors can be logically and profitably applied. Logical applications include those where: (1) higher than normal ambient temperatures are encountered, (2) small space and low weight are of prime importance, and (3) in fan cooled motors, particularly in the larger sizes. Large volume, Summers adds, will not be achieved until it is demonstrated that it is economical to use Class-F motors where standard open Class-A and B motors are now used.

In an economic evaluation of the Class-F motor, Summers points out that the lower initial cost (since the unit is now smaller and hotter) is balanced by the increased operating costs due to lower motor efficiency caused by the reduced volume of material and the higher operating temperature of the copper. As a result of his appraisal, using the usual techniques of engineering economics, he concludes that despite lack of classification standards, Class-F systems will increase in usage. He feels there is a good chance Class-F motors can replace the present standard Class-A motors and provide an economic advantage.

MAGNET WIRE INSULATION

In a paper titled "A Magnet Wire for Class-A, Class-B and Class-F Applications, Ralph W. Hall of Phelps Dodge Copper Products Corp. suggests consideration of a single magnet wire for all three applications. His aim is to simplify the problem of evaluating and stocking a great variety of different types.

The root of the problem in achieving this aim, he says, is the unusual combination of physical, chemical, thermal and electrical properties required in the insulating film for successful use in electrical equipment. These include: flexibility, good abrasion resistance for winding, chemical stability and solvent resistance, and preservation of electrical properties against time and temperature for the design life of the application. Additional requirements are good form stability at the temperature extremes encountered and high dielectric strength maintained under all environmental conditions of service.

As a result of this diversity of desirable properties, whose relative importance is a function of the particular application, manufacturers have developed a great variety of magnet wire insulations based upon synthetic resins. Although individual properties of one resin may be better than those of others, the problem is to find the best balance of properties. This requirement not only imposes a dfficulty on the user who must choose the best insulating film for his application, but on the manufacturer as well who, because of competitive pressures, must have a great number of varnish systems in his plant to produce the large variety of grades required. "Actually," Hall points out, "in many areas of application one magnet wire product is merely a substitute for another – without any

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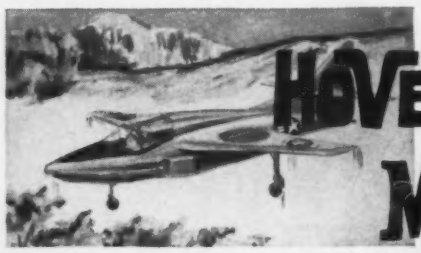

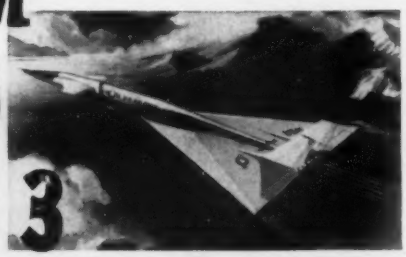

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advantage to the user. The problem facing purchasing people as they try to hold their inventory dollars down is obvious."

The basic fact that stands out is the need for a film wire for higher temperature operation without sacrifice of insulation life. Although very high temperature magnet wire insulations are available, they are usually poorer in space factor, or cost much more. What is really required is a balanced property insulation for magnet wire with Class-B and Class-F rating at no increase in cost, that also could be used for Class-A.

Hall suggests that when the basic properties of all the synthetic resins used on magnet wire today are compared with respect to industry's needs, a polyester resin based on terephthalic acid stands out, with more than adequate thermal life, good physical and chemical properties, and low production cost. The one glaring weakness, limiting its wide acceptance for Class-A,-B, and-F temperatures is referred to by Hall as "heat and solvent shock failure." This weakness is evaluated by Phelps Dodge as follows: Heat Shock Test – Wire is stretched 15% and wound on a 3X (three times bare diameter) mandrel. Samples are subjected to +175°C for 1 hour. Solvent Shock Test – Samples (as above) are subjected to 10 minutes in boiling xylene (135°C).

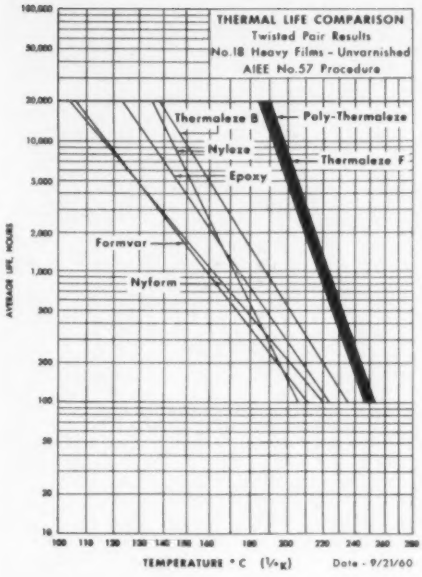

Fig 2. Comparison of the life vs temperature characteristic of Phelps Dodge's Poly-Thermaleze with other insulations.

Failure in the heat shock occurs as a result of loss of tensile strength at high temperature causing cracks to occur in the film. The solvent shock test can relate to what happens during varnish treatment, particularly when motors are dipped hot.

Hall states that a new polyester based wire film, Poly-Thermaleze by Phelps-Dodge does not show the heat and solvent shock failures characteristic of the conventional polyesters, thereby overcoming the glaring weakness mentioned above. This achievement is based upon applying an additional thin layer on top of the conventional polyester coating. This outer layer is a high-molecular-weight linear polymer of high tensile strength when hot which effectively eliminates heat and solvent shock failures. Thus the high temperature properties of the polyester may be taken advantage of extensively in Class-A,-B, and-F systems without sacrifice in economy, and at a great simplification of wire evaluation and stocking problems. Fig 2 compares life vs temperature characteristic of Poly-Thermaleze with a variety of other insulations.

Evaluation Techniques

Discussing the need for functional evaluation of insulation systems, J. R. Learn, W. J. Sherburne and W. Viscusi of General Electric, Schenectady, N.Y., in a paper "Functional Evaluation of Class-F Systems," propose methods for carrying out the evaluation rapidly and economically.

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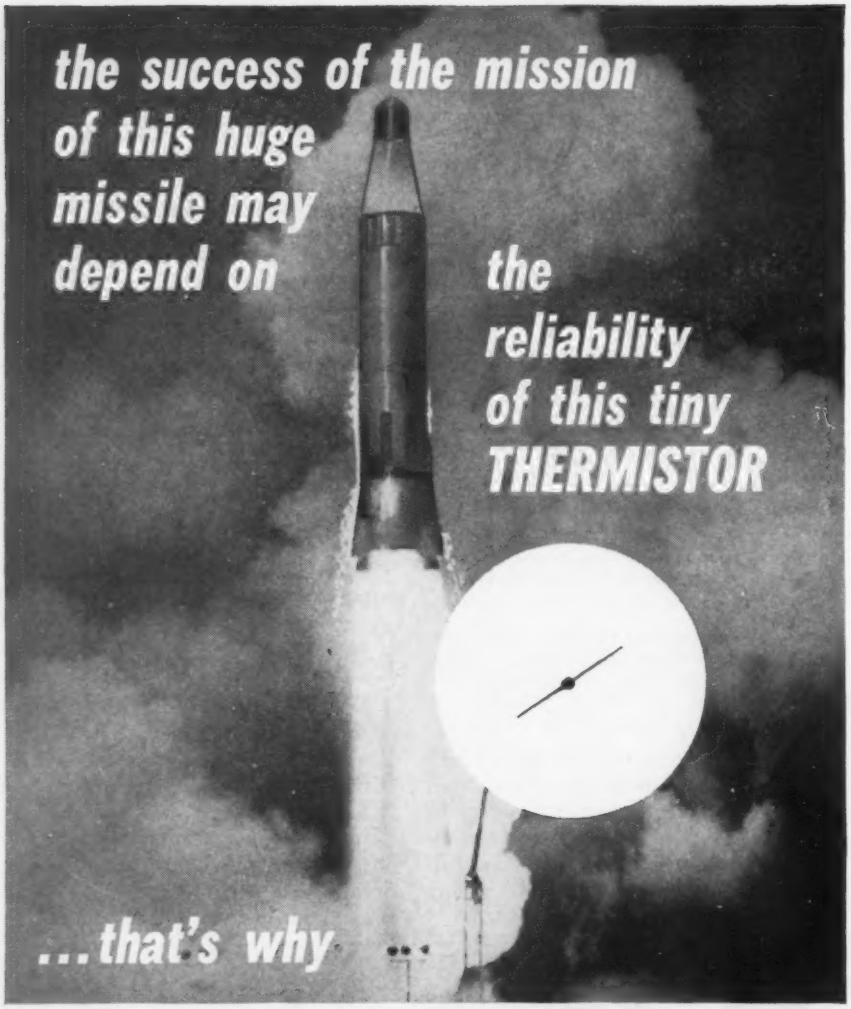

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wide use today, including twisted pairs, AIEE Procedure #57, and motorettes, AIEE Procedure #510, are useful and reliable tools for evaluation of simple wire and varnish combinations and simple random-wound motor systems, providing information on thermal life and practical information for correlating with known service conditions.

The authors, in evaluating Class-F systems, have continued to use the twisted pair and the motorette. In addition, they have been working on the development of new functional test models to simulate random wound, form wound, and layer wound constructions using magnet wire, varnish, and ground and layer insulation, using cycling procedures similar to those of AIEE #57 and #510, but adapted to Class-F systems. They describe a number of special models developed for their evaluation program:

Slotette – For evaluation of slot insulation. The slotette uses a section of an integral horsepower motor stator with round bottom slots of specified dimensions. Slot liners are installed, and a specified number of strands of wire are wound to simulate the slot portion of a random wound coil extending out from one to two inches beyond the slot on both sides. Topsticks are melamine glass laminate. To prevent flashover, ends of the wire bundles are taped with mica mat tape and dipped in varnish up to 1 inch from the slot. The slot sections are not varnished. Cycles consist of thermal aging at three temperatures, followed by 16 hrs at 2 kv and 48 hrs at 100% RH, 100°F. Thermal aging periods are determined by AIEE 1D recommendations.

Cablette–For measurement of power factor, temperature, voltage relationships, corona start voltage vs temperature, and voltage endurance tests on insulation systems used in cable and on high voltage rotating machinery. Physically they consist of a minimum 24-inch copper tube, 1-inch OD, helically taped with 1-inch wide insulating tapes. Besides evaluating varnished and unvarnished systems for high voltage applications, cablettes are used for studies of methods of taping, and comparison of taping patterns, curing and molding techniques, and molding and forming operations. Variations are described for power factor determinations and voltage endurance.

Modified Transformerette–This is a simple device incorporating the basic

elements found in a transformer, a magnet coil, or a field coil. It is essentially recommended for screening the various components. Physically the modified transformerette consists of a rectangular steel cone of specified dimensions around which is wrapped the material to be evaluated as the ground insulation. Two single layer coils are installed, one directly around the other to provide two layers of magnet wire for wire-to-wire, as well as coil-to-ground, testing. A wrap of layer or phase insulation is applied, followed by two more single layer coils. An outer wrap is applied last. A varnish treatment is applied to evaluate various impregnation processes. These structures, suitable for measurements of dielectric strength, corona start voltage, and insulation resistance, can be evaluated according to AIEE #510 test procedure.

Form Wound Motorettes—The scope of the motorette for evaluating insulation systems is broadened to include form windings. Standard motorette frames are converted to accept form-wound coils by adjusting the sides of the slots to be perpendicular to the base. Due to the size of the slots, the form wound motorette is probably most useful for evaluating insulating systems for low voltage machines. Exposure conditions for all types of motorette constructions may include water, solvent, or refrigerant immersion, salt spray, mechanical shock, or extreme thermal shock, in addition to or in combination with the heat aging, vibration and humidity cycles of AIEE #510.

Tests, in addition to voltage, include repetitive surge, insulation resistance, and corona starting level.

The authors conclude by pointing out that the value of these modified or simplified functional tests seems to bear the same relationship to the work done on developing the formette, the full

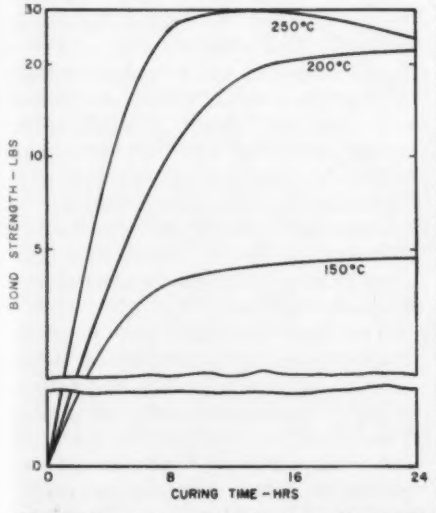

Fig 3. Bond strength of conventional silicone varnish vs curing times at 150, 200 and 250°C.

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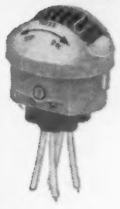

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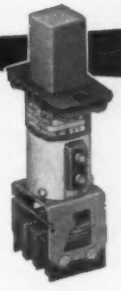

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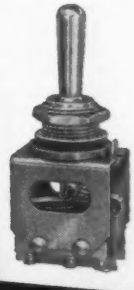

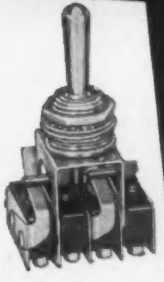

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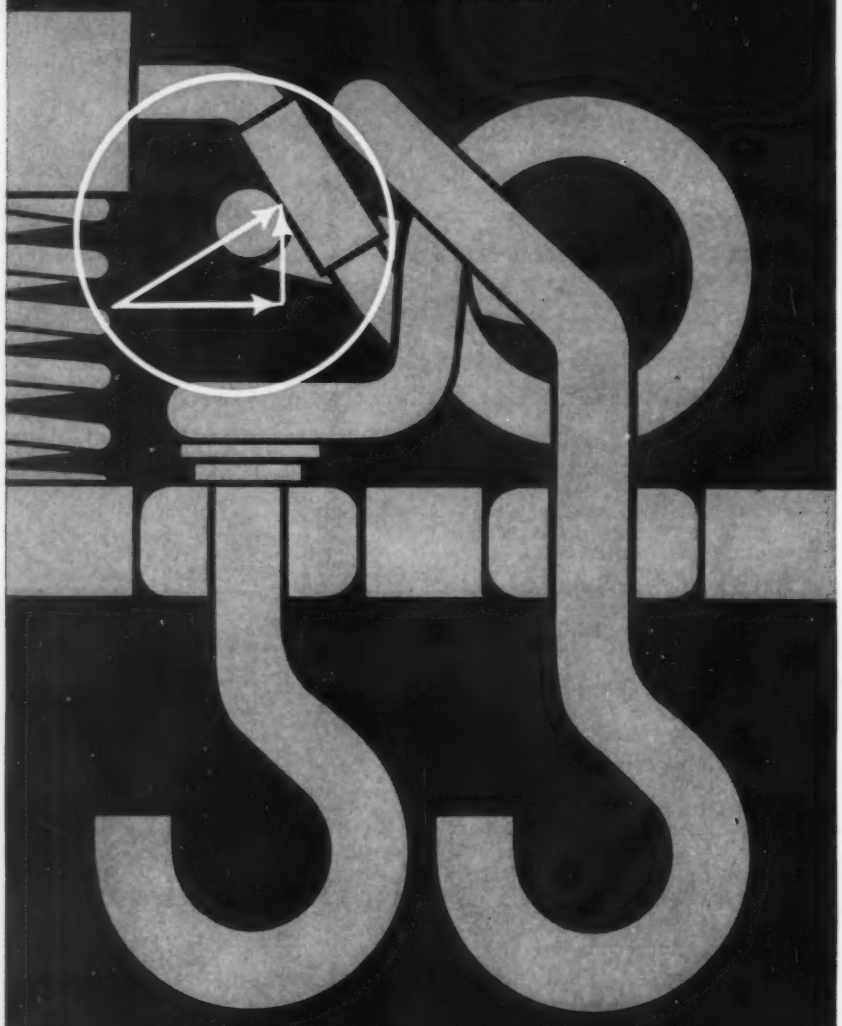

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COMPONENTS DIGEST

transformerette model, and the larger models such as the fieldette and the generette that the twisted pair, Procedure #57, bears to the Procedure #510 motorette with which life data correlates extremely well in most cases. If such a relationship is borne out, these simple devices will be able to screen a great many systems out of which the most promising can be evaluated by models closer to actual equipment in size as well as design.

PRELIMINARY TESTS

W. B. Penn of General Electric, Erie, Pa., in a paper "Evaluation of New Materials for DC Motors and Generators," points out that in many instances, standards of testing, methods of classification, and appropriate definitions have not been established, and yet manufacturers make claims about performance based upon individual evaluations within their own manufacturing plants. Even when a conscientious manufacturer presents data, in complete tabular form, defining at the same time the tests to which he subjected his material, the insulation engineer must still evaluate the material for his application. The reasons are the necessity of applying the material to the very specific range in which it will be used, as well as to determine the compatability of the material with other elements of an insulation system that have already been proven out for the application.

The main theme of Penn's article was that a preliminary screening and evaluation is necessary prior to an intensive and large scale evluation of an insulation. Since large scale evaluation is an intensive and time consuming process, this preliminary screening based upon the use of simple samples is of greatest value. Preliminary screening eliminates those materials which would otherwise fail early in a large scale test program. Penn's paper describes some of the procedures by which new materials are evaluated and screened by the DC Motor and Generator Deprtment of the General Electric Company in Erie.

The first screening test Penn described is the "compatability test" which aims to check compatability between insulations and impregnating compounds. This test was introduced at the G. E. Laboratory at Fort Wayne for the evaluation of polyester enameled magnet wire for Class-B machines, since this type wire apparently possessed greater sensitivity to chemical interaction than

wires previously used. The test was carried out by sealing within a clean, dry bottle five samples (twisted pairs) of the wire as well as a sample of the material whose compatability with the wire was to be ascertained. This sealed bottle was held for two weeks at 180°C. At the end of this time the bottle was removed, cooled, and opened. Hi-pot tests and dielectric brake-down voltages established the basis of comparison between new and previously employed insulations. The author points out that this test is severe, perhaps overly so. However, he feels it presents valuable information by merely a visual inspection of the wire enamel at the conclusion of the test. Tendencies to flake or to gum indicate deterioration. Sealing the twisted pairs with a small quantity of water makes it possible to determine hydrolytic stability (the ability to withstand moisture). Breakdown values after a two-week exposure period differentiate between various wire enamels.

Penn describes a simple screening test for comparison of compression creep. This test evaluates the use of sheet laminates under compression loading. Insulating washers, for example, must exhibit good compression creep qualities. In this test, the laminate in question is fastened into a compression washer. A number of such washers are mounted on a steel ring. The ring has many threaded holes into which the sample is bolted by means of a torque bolt and a compression washer. A very specific amount of force is applied to the bolt to tighten it down. A scribe line on the head of the bolt indicates the position of the bolt at start of the test. After heat ageing at various temperatures, and various stages of the ageing cycle, the samples are cooled to room temperature and torque is re-applied to its original value. In doing so the scribed line on the head of the bolt is displaced from its original position. The movement of the bolt, measured as an angle, becomes then a measure of the compression creep of the insulating laminate.

For good accuracy the thread friction must be reduced as far as possible by working the bolt several times in its initial assembly and by lubricating it with some solid lubricant. Penn says that consistent and reproduceable results are easy to obtain, however. Valuable information on pre-baking and ageing are likewise readily available directly from this test.

Bonding Strength – A simple screening test for comparing the bonding strength of varnishes was devised, consisting of dipping two rectangular magnet wires into the varnish being checked, overlapping the dipped ends for a distance of 1 inch, and holding

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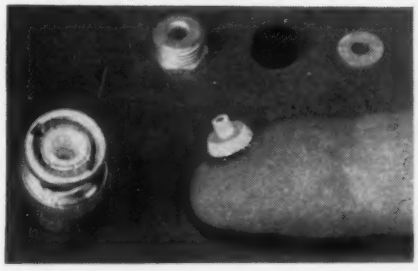

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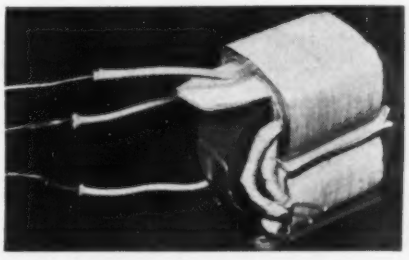

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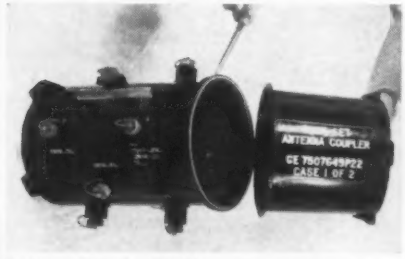

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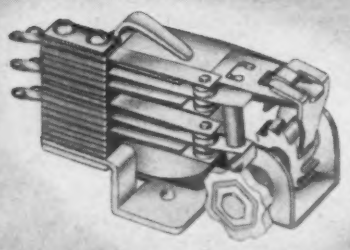

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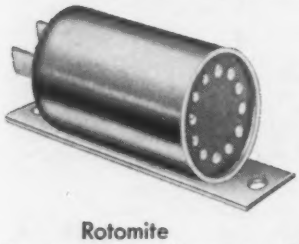

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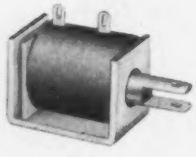

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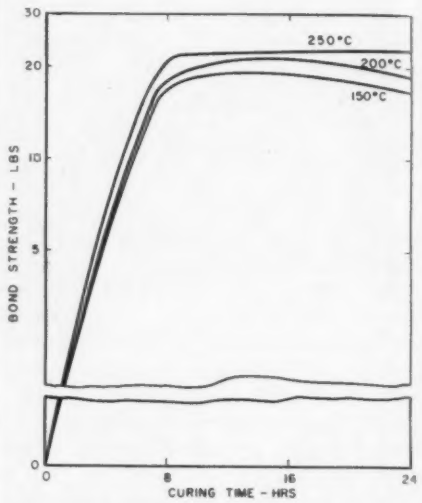

Fig 4. Bond strength of a low temperature-curing silicone varnish vs curing times at 150, 200 and 250°C.

these in intimate contact by means of a clip. The structure is then baked in a prescribed manner. This simple technique permitted the making and testing of a large number of samples. A pull test is used as a measure of bond strength.

Statorette Tests – Statorettes have been described elsewhere in this presentation. Discussing the usefullness of the statorette in evaluating ground insulation and varnish, Penn said that samples prepared can be readily used for testing of heat ageing, vibration and humidity effects. As screening progresses, the number of candidates for each insulation function gradually narrows so that later statorette designs are built up from the best combinations of slot insulation and varnish determined from the previous tests.

By means of these screening tests, Penn feels that a great deal of time and money will be saved in the preliminary evaluation stage so that a much more detailed evaluation of the insulation system will be possible.

VARNISH EVALUATION

In a paper "Evaluation Procedures for Electrical Insulating Varnishes", C. F. Hofmann of Westinghouse Electric Corporation, East Pittsburgh, Pa., discusses evaluation techniques which have been developed during the past ten years by Westinghouse for selection of Class-H insulating varnishes. The paper includes a description of the test

methods used in the evaluation. Hofmann says that these methods can be modified to include all classes of insulating varnishes. The most important characteristics in selection of a varnish suitable for most insulation applications, he says, include: 1. curing characteristics of the varnish, 2. thermal stability of the varnish, and 3. thermal stability of the varnish in combination with wire enamels.

Curing characteristics. Two procedures are used to determine curing characteristics. The first involves the coating of steel panels with the varnish in question and examination for tackiness, lifting, and non-wetting properties after various curing conditions. The second procedure involves coating of wire coil specimens with the varnish and testing them for maximum varnish strength after various curing conditions.

In the first test a series of panels is coated with two consecutive varnish coats in a prescribed manner. Enough panels are used so that curing cycles ranging from 1.5 hours to 72 hours at any recommended curing temperature are available. The cured, varnished panels are then tested for tackiness at 25°C and 200°C by wiping the surface with a white cotton fabric. When properly cured, no fibers adhere to the surface.

The panels are examined for lifting, a condition where the first varnish coat is insufficiently cured and is attacked or redisolved by the varnish solvents of the second coat. Lifting can usually be eliminated by increasing the curing time or temperature of the varnish.

Non-wetting is usually caused by over-baking the first varnish coat and can usually be eliminated by reducing the curing time or curing temperature.

A procedure is used to evaluate maximum bond strength of the varnish in various curing temperatures. Standard helical coils are dipped in the varnish and cured under various conditions of time and temperature. The force required to break these coils in flexure is called bond strength.

Figures 3 and 4 show typical bond strength characteristics for silicon varnishes after they are at various temparatures. Figure 3 shows a conventional silicon varnish requiring a rather high temperature cure. Figure 4 shows one of the newest silicon varnishes which may be cured at low temperature.

These test of curing characteristics, including tackiness, lifting, wet-ability and bond strength, are taken together to establish the best cure for a particular silicone varnish. By modification of temperature and curing conditions, this procedure can be adapted to all classes of insulating varnishes.

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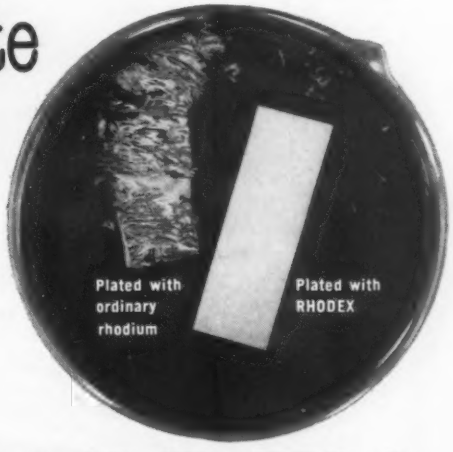

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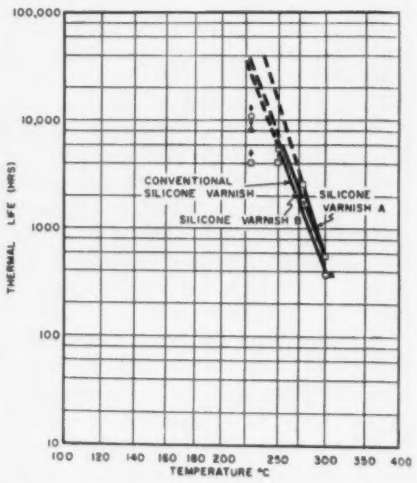

Fig 5. Relative thermal life of silicone insulating varnishes (curved electrode method-300v/mil).

importance. Hofmann points up the utility of the suggested ASTM method for evaluation of thermal stability by the curved electrode method. This method incorporates such variables as weight loss, retention of flexibility, thermal shock and shrinkage into a useful test which yields reproducible thermal stability data.

The test consists of measuring the electric strength of varnish to glass cloth panels using a curved electrode test fixture. Specimens are aged at 3 or 4 temperatures depending on the class of insulation until the electric breakdown strength increases to a specific value. Thermal life, or the number of hours for the electric strength to decrease to the specified value, is plotted on a logarithm time scale as a function of the reciprocal of the absolute temperature, to produce a graph of the thermal stability of the insulating material. This procedure is readily adaptable to measuring the relative thermal stability of the silicon varnishes. Varnished glass-cloth panels are used and cured by recommended curing schedules described above. Hofmann employs ageing temperatures of 225, 250, 275 and 300°C for evaluating Class-A varnished, and electric breakdowns are determined at various intervals. He defines failure as the point at which dielectric breakdown value decreases to 300 v per mil. Figure 5 shows thermal life data for a conventional silicon varnish and two low-temperature-curing silicon varnishes.

Although the thermal stability of an insulating varnish is an extremely im-

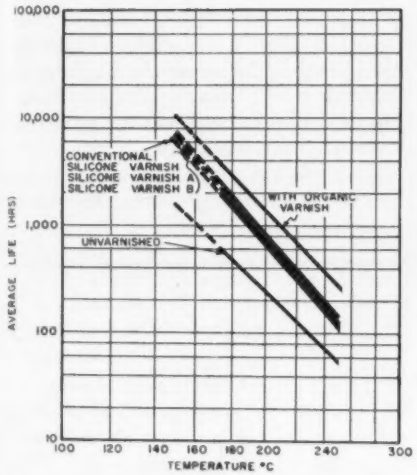

Fig 6. Thermal life of an epoxy modified polyester wire enamel with various varnish treatments.

portant factor, when the varnish is used in combination with other insulating material its thermal life can be either greater than or equal to or less than its uncombined life, which is merely a restatement of the importance of compatability. Hofmann recommends AIEE No. 57, "Evaluation of the Thermal Stability of Enameled Wire" which has been widely and successfully adopted to determine the relative stability of wire enamels. Hofmann uses this procedure as a measure of the compatability of insulating varnishes and wire enamels.

Briefly this method consists of the ageing enameled wire twist specimens which have been treated with the insulating varnishes. At various intervals the specimens are removed from the ageing ovens and a specific voltage is applied. If the specimens do not fail they are returned to the oven for further ageing. When all the specimens have failed, the average life of each exposure temperature is calculated and plotted on a logarithm time scale as a function of the reciprocal and absolute temperature. The resulting straight line functions represent the thermal stability of a particular system and can be compared with other systems. Figure 6 is typical of the characteristics obtained in this manner. The author illustrates the compatability factor by showing a whole series of plots similar to those of Fig 6 in which various wire enamels are used with an assortment of varnishes indicating the thermal life.

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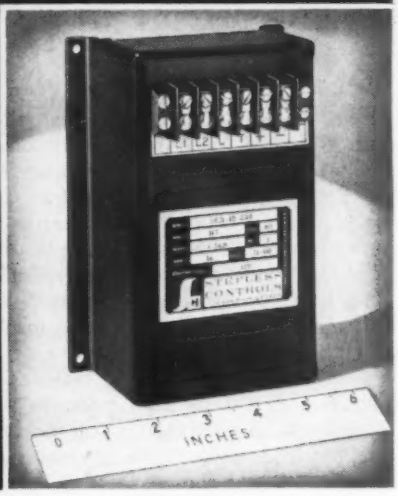

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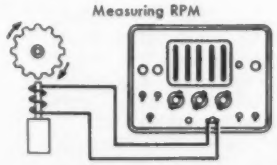

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rubber are its excellent thermal stability and electrical performance combined with seal-ability. R. S. Armstrong and R. A. Ward of General Electric Co., discuss in, "Silicon Rubber Insulation Systems and Processes", the application of silicon rubber tapes with particular consideration of materials and processes necessary to fabricate a reliable insulation system.

One of the most striking features of silicon rubber is its high moisture and environmental resistance which makes it possible to do away with expensive enclosures for equipment located in wet or dusty atmospheres or exposed outdoors. Use of reinforcing fabric in the insulation adds to mechanical strength and does not adversely affect performance as measured by voltage endurance, corona spark voltage and insulation resistance data. Other excellent properties include ease of handling in a moldable semi-cured state and its suitability to the manufacture of void-free sealed systems. Its principal deficiency is its relatively poor mechanical strength which has led to incorporation of reinforcing fabrics in silicon rubber systems.

An important consideration in silicon rubber systems is treatment and cure of the rubber for maximum chemical resistance and stability. Tapes recommended for reinforced systems should be partially cured and moldable. After vulcanization the sealed system is integral with the rubber forming a continuous cohesive mass through each tape layer. Systems reinforced with polyester glass fabrics stand considerable distortion without damage.

Discussing dielectric properties, basic characteristics of insulation systems, the authors point out there is a considerable spread in published data on reinforced and unreinforced systems. They indicate that for equivalent thicknesses, reinforced structures have a slightly lower short-time dielectric strength. However, of greater significance is the ability of the system to withstand operating voltage stresses over long periods of time and to have good voltage endurance. In Fig 7, the authors show that reinforced and unreinforced rubber systems have equivalent voltage endurance life at voltages well above anticipated operating stress levels.

The authors state that corona start-voltage level of typical reinforced sys-

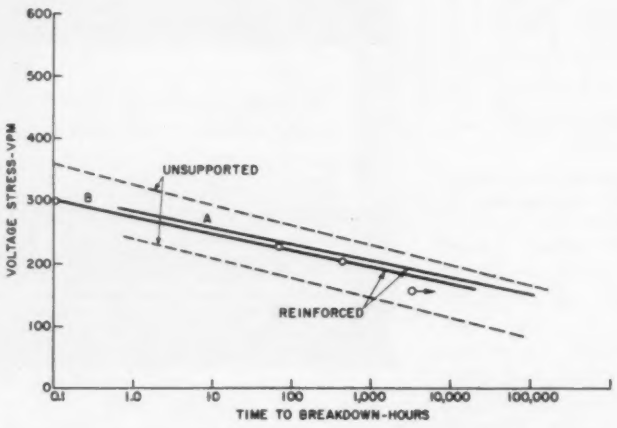


Fig 7. Voltage endurance of silicone rubber insulation systems.

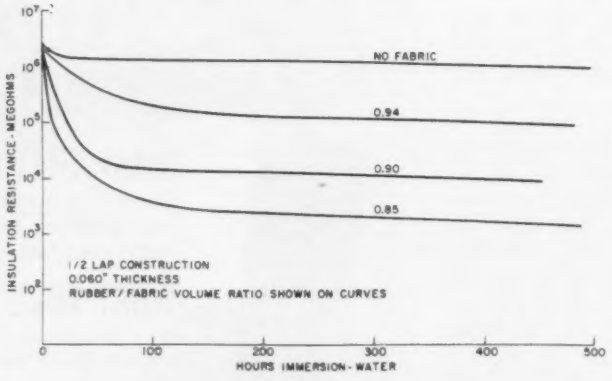


Fig 8. Insulation resistance of silicone rubber insulation systems.

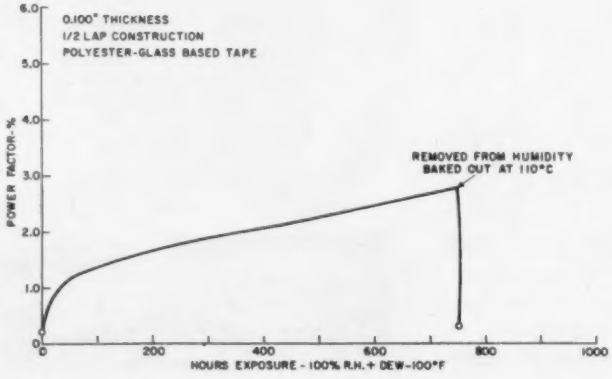
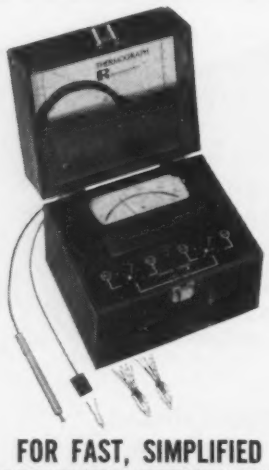


Fig 9. Power factor—reinforced silicone rubber insulation system.



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tems demonstrate that these materials offer adequate protection to voltage requirements placed upon them. The high corona start voltage in conjunction with the outstanding resistance to corona damage of silicon rubber further justify its use in high voltage applications.

Figure 8 shows insulation resistance of various structures. All measurements were made on tape half-lapped over bare stranded wire built to a thickness of 60 to 65 thousandths inch, using semi-cured unreinforced tape or semi-cured polyester-glass reinforced tapes of different relative fabric ratios expressed on a volume basis. Although the insulation resistance characteristics of the unreinforced rubber was obviously superior, in all cases the insulation resistance was greater than 1000 megohms.

Figure 9 considers moisture sensitivity from another point of view. The figure shows the power factor of a sealed polyester-glass reinforced taped structure as a function of exposure to humidity plus dew. At 100°F and 100% relative humidity, the power factor, extremely sensitive to moisture content, increases slowly. Removal of the samples left to humidity exposure followed by a baking at a 100°C restores the power factor to its original value. These data indicate that moisture absorption is a reversable non-degrading phenomenon and does not particularly affect performance at the normal operating temperature of silicon insulation.

Cure – A very simple type of curing process for silicon rubber insulation is application of a heat shrinkable tape as a source of pressure on top of the silicon tape. Parts processed in this manner can be over-cured in 15 to 30 minutes at 150°C. At that time, the shrinkable tape is removed prior to a final baking operation. This procedure provides a compact vulcanized finished part. During the process sharp edges should be avoided where the excess pressure exerted by the shrinking tape tends to reduce the corner fitnesses. Chief advantage of this process is minimum equipment. High dielectric strength and good insulation resistance are achieved.

The authors describe what they refer to as "fluid compacting". Here, certain very hot liquids and gases under pressure are used to densify and cure silicon rubber. Latent heat in gasified liquids can also be used to advantage. This system permits uniform pressure application in relatively low cost processing equipment.

The process requires exposure of the tape structure to 60 to 100 psi at 135 to 160°C for a period of 10 to 20 minutes, after which it must have a final bake for ultimate cure. The tape

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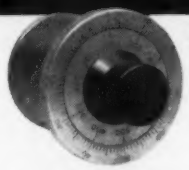

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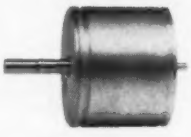

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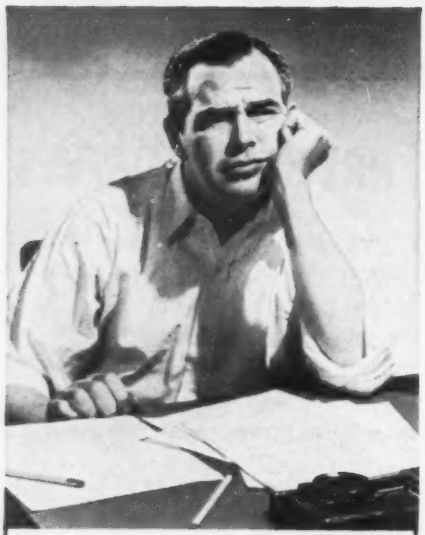

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COMPONENTS DIGEST

structure is readily protected by coating it with some kind of dip coat or enclosing it in an encapsulating bag. This helps maintain the pressure differential required for cure and to prevent impregnation by the pressure medium. Where configuration of the insulated parts permits, conventional molds or presses can be used to supply the necessary pressure and heat for densification and cure. The authors emphasize the importance of the final baking operation to gain full inherent thermal and environmental stability of the material. In Fig 10 they show the importance of this post-bake in relation to the physical properties of the silicon rubber. A final recommendation is to post-cure all silicon insulation at as high a temperature as practical, at least 40°C.

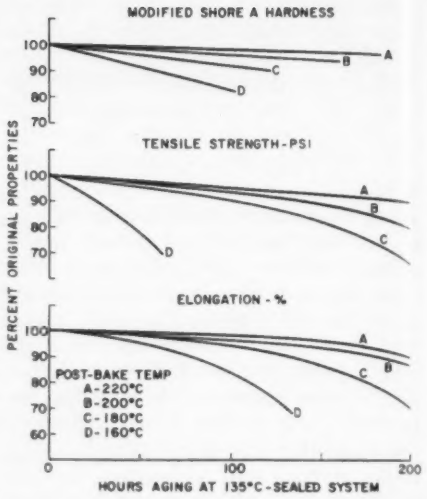

Fig 10. Physical properties of silicone rubber aged in sealed system at 135°C vs post-bake temperature.

Pressure Sensitive Tapes

In "Thermal Classification of Electrical Pressure-Sensitive Adhesive Tapes", Roger E. Hudrlik and Ward M. Hanson of Minnesota Mining and Mfg. Co. present data on the high-temperature ageing characteristics of Class-A,-B, and-H pressure-sensitive tapes. Data is plotted as a semi-log plot against the reciprocal of the absolute test temperature, to predict service life.

In evaluating the tapes the authors considered both electrical and mechanical properties that may be functions of the adhesive or backing. The variables

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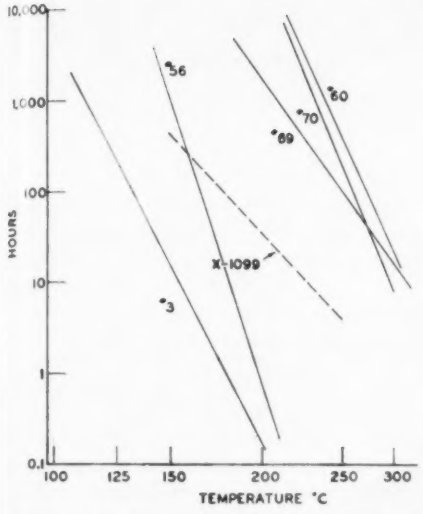

Fig 11. Temperature effects on flex failure.

studied were adhesive shear strength, insulation resistance, electric strength, curved electric strength and MIT flex.

To measure the holding power of the adhesive and to some extent the strength of the backing, adhesive shear strength was tested, which involved application of a ½" x ½" area of tape in contact with an ASTM steel adhesion panel.

A new curved-electrode test developed by ASTM in conjunction with sheet insulation tests midly flexes the aged sample. The authors expect this test will yield more practical values of insulation strength since some dynamic stress is always encountered in service. Three tests are carried out: insulation resistance, electrical strength, and curved electrical strength.

From a purely mechanical standpoint the flex-test developed at MIT was employed to check folding endurance of the material. In this test, standardized as ASTMD-643, a ½ inch-wide strip of tape is clamped in position and loaded in tensile with a 1.5 kgm weight. The machine then automatically bends the sample through an angle of 135 degrees in both directions from the zero-fold position until it breaks. The severity of the degree of flexing in comparison to the curved electrode test means that relatively-short test time is required.

The authors conclude by pointing out the usefulness of the MIT flex-test as a means of predicting service life at high temperatures for thermosetting electrical pressure-sensitive adhesive tapes. Results are obtained relatively quickly that correlate well with field usage conditions. For materials with high initial flex life the failure criterion of 250 flexes correlates well with field experience. For materials with low initial flex life, 10% of the original correlates better with field experience. Figure 11 illustrates the kind of curves that may be plotted for predicting life based upon flex failures. The numbers refer to specific varieties of tape by Minnesota Mining & Mfg. Co.

Red-Hot Components

L. F. Kilham of Raytheon Co., in a paper discussing the design of components for 500°C ambient operations, notes that there appears to be two distinct and opposite component design approaches to extreme high temperature equipment environments. The first approach is the selection of suitable temperature resistant materials and the application of special techniques to design components to withstand the severe extremes of temperature. The other approach is the simple expedient of operating conventional components in a cooled atmosphere. The latter approach, Kilham believes, may inflict a penalty of an overall increase in size and weight.

Kilham points out that the thermal endurance of organic insulation, limited by effects of oxidation and pyrolysis, has been the determining factor in the upper temperature limit of component operation. At high operating temperatures it becomes necessary to find inorganic substitutes for their more familiar organic counterparts.

Insulating materials suffer severe deterioration at high temperatures. A plot of typical resistance values versus temperature (Fig 12) indicates that resistance values in the range of 1,000,000 megohms at room temperature may drop to 100 megohms at 600°C. Kilham attributes this drop to the fact that conductance in good insulators is mostly ionic and the mobility of ions increases with temperature. The presence of alkali metal ions in glass is a contributing factor to its relatively poor insulating properties at high temperature.

The author describes a new type of flexible insulation, developed at Raytheon, based on the bentonite clay film studies by Dr. Ernest Hauser of M.I.T. during the 30's. To improve the tensile and tear strength of this clay film, a quantity of inorganic fiber such as glass, quartz, aluminum silicate or potassium titanate was added. A thin coating of silicone resin gives added strength. Films of five ten-thousandths of an inch, with breakdown voltage of 1500 volts per mil, have been made. Discussing the problems of obtaining a good insulating environment at high temperatures, Kilham states that most good insulating liquids at room temperatures do not remain in the liquid state at 600°C or lose their good insulating properties. Of the few that meet the requirements, their thermal expansion is such as to make their use impractical. He points out that the packaging of ultra-high temperature components and

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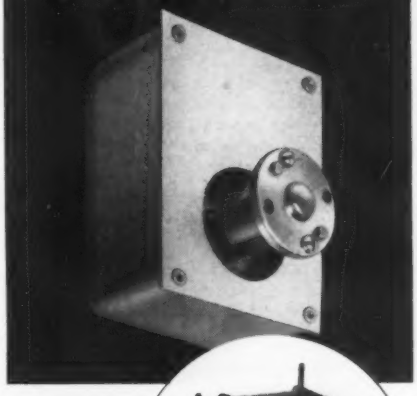

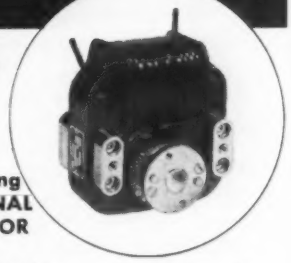

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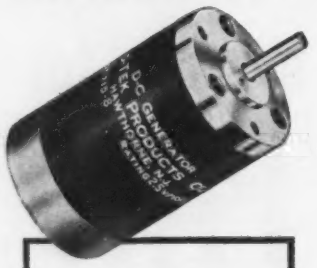

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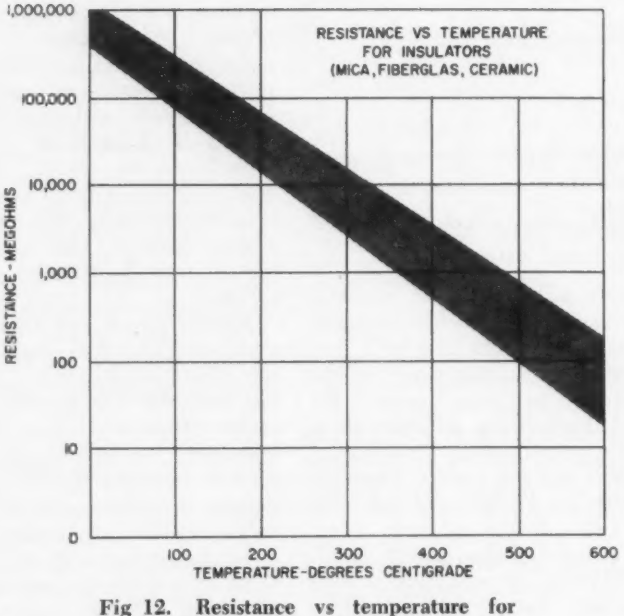


Fig 12. Resistance vs temperature for insulators such as mica, fiberglas and ceramics.

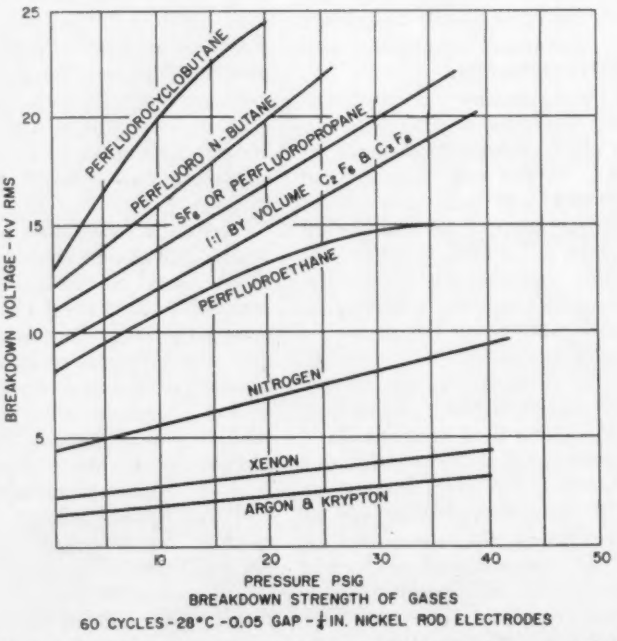


Fig 13. Although several of the gases of higher dielectric value are stable at 300°C, at 600°C unfortunately these gases are thermally unstable. At 300°C, Perfluorethane appears to be adequately thermally stable and at 600°C it is necessary to use nitrogen at pressures as required to meet the dielectric requirements. These pressures may be as high as two to three atmospheres at room temperature. All containers used to enclose a dielectric atmosphere must be thoroughly tested against leaks and in large units have protective elements. It is common practice to use a Helium Mass Spectrometer to detect leaks in containers. Various protective devices, such as pressure or density switches, are used on larger units.

systems in a sealed inert gas atmosphere offers many advantages. Selected gases offer adequate dielectric protection as shown in the plot of Fig 13.

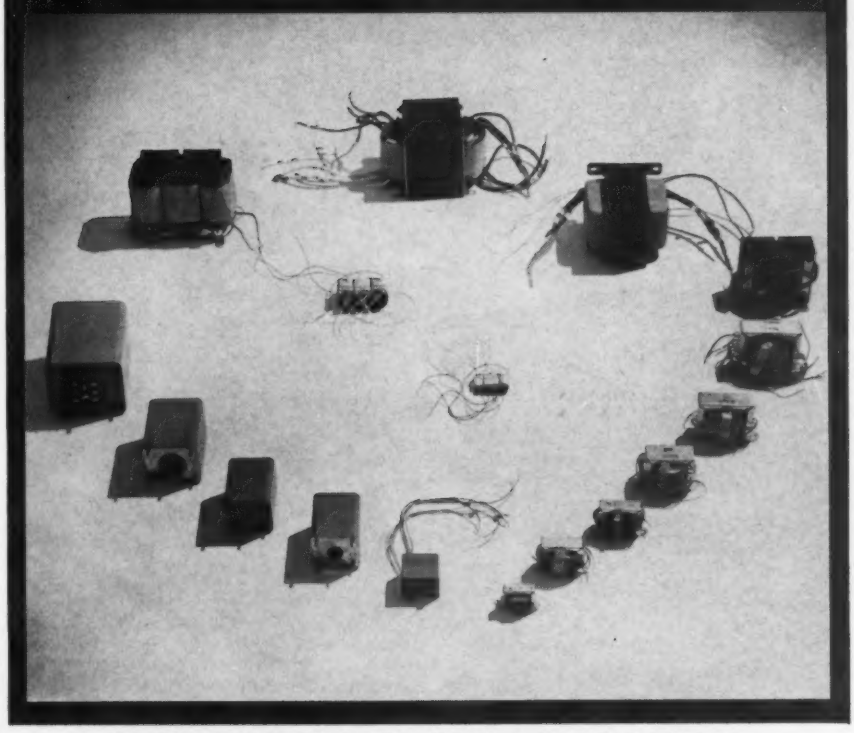
The author characterizes adhesives and potting compounds as examples of materials which serve dual functions as insulators and structural members. As a result of recent developments, it has been determined that certain types of silicone resins which are unstable when exposed to air at temperatures above 250°C can be used in inert gas atmospheres up to 600°C. To accomplish this, the material must be degassed under vacuum at a high temperature following the usual 200°C cure. Weight loss when heated in vacuum at temperatures up to 600°C is in the order of 25%, as compare with 50% for the same resin heated in air, indicating that a large portion of carbon still remains in the molecule after vacuum treatment. Properly selected resins retain a large measure of their bonding strength, exhibit excellent electrical properties, and can be operated for long periods at very high temperatures without further degradation. By admixture with refractory powders and inorganic fibers, potting compounds of zero shrinkage and controllable porosity, resistant to shock and vibration, may be compounded.

The problem of high temperature wire insulation has not been completely solved, Kilham believes. A quick look at available high temperature insulated conductors shows present wires of fiberglas served copper and silver, anodized aluminum and a variety of ceramic coated nickel clad copper wires. The glass served wire presents excellent performance at high temperatures but relatively poor space factor, Kilham contends. "This problem, he says, is brought into focus when one realizes that a coil of #40 glass served wire has a copper volume of only 17%."

Anodized aluminum also has its disadvantages, according to the author. The difference in coefficient of expansion of the insulation and the conductor gives rise to serious faults of the insulation under temperature changes. Its conductivity is only 61% of copper and its melting point is low at 650°C.

He also points out that nickel clad wires, in the smaller sizes, show a considerable increase in resistance under high temperature conditions. This increase in resistance is due to the diffusion of nickel into copper with formation of an alloy of high resistance. The

TRANSFORMERS



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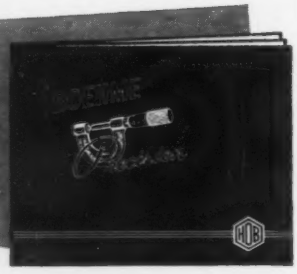

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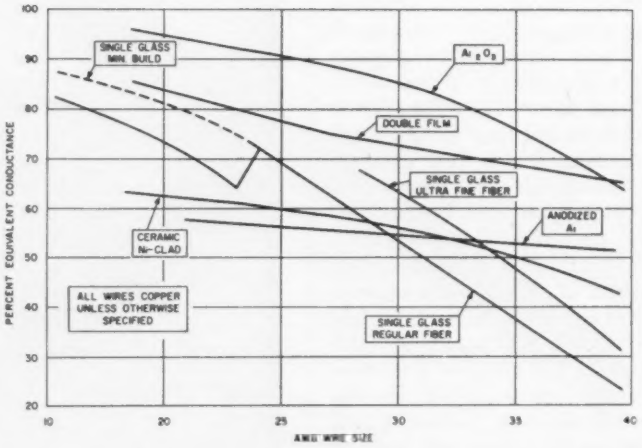

Fig 14. Curves show relative conductance (% conductivity relative to copper times the volume of metal divided by the total wire volume) for various wires. The term "double film" refers to conventional double organic film coated wire. The wire shown at the top, developed by the Industrial Components Div. of Raytheon, utilizes a technique previously used in the coating of tungsten filament wires. Because of its excellent space factor, commensurate with dielectric protection, Raytheon recommends this wire for use in inert atmospheres at temperatures up to 400°C.

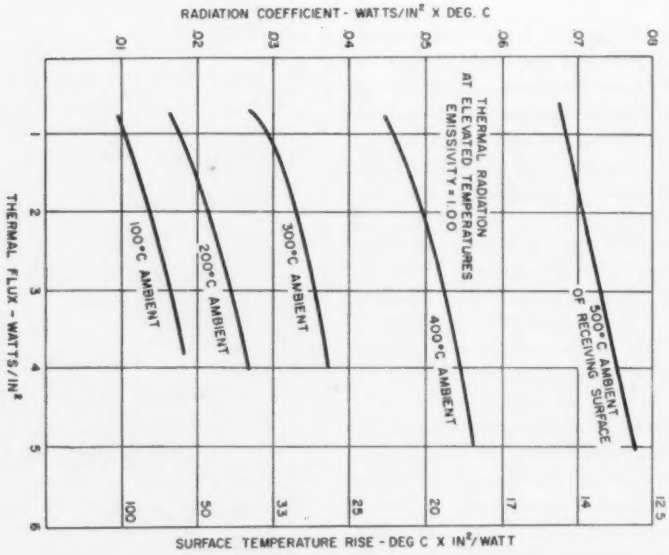
RADIATION COEFFICIENT - WATTS/IN² X DEG. C
THERMAL FLUX - WATTS/IN²
SURFACE TEMPERATURE RISE - DEG C X IN²/WATT
THERMAL RADIATION AT ELEVATED TEMPERATURES EMISSIVITY = 1.00
100°C AMBIENT
200°C AMBIENT
300°C AMBIENT
400°C AMBIENT
500°C AMBIENT OF RECEIVING SURFACE

Fig 15. Plot of radiation coefficient at ambient temperatures up to 500°C. Curves show that radiation heat transfer at 500°C is six to seven times as effective as at 100°C. Temperature gradients inside and outside the equipment container may be minimized by coating all surfaces with a high-emissivity finish. Natural metal oxide finishes provide some improvement in radiation, but a more effective method, applicable to stainless steel and nickel, is to immerse the metal in molten sodium dichromate at 400°C. This treatment yields a thermally and optically black surface coating which is resistant to corrosion at high temperatures.

present state-of-the-art of high temperature conductors, as summarized by Kilham, is shown in Fig 14.

A quick look at the magnetic materials for use at high temperatures discloses that radical changes occur in their characteristics. Although core losses at the higher flux densities and high temperature decrease, the exciting current increases. As the temperature approaches the Curie point of the core material, increase in current makes it necessary to lower the maximum flux density by about 15%. Interlaminar insulation resistance deteriorates severely at these temperatures. To offset this, a mil layer of inorganic insulation may be added.

At elevated temperatures, various brazing techniques are utilized. At 350°C, torch brazing is used while at 600°C, heliarc welding has been applied. Various techniques for metalizing high density alumina ceramic terminals have been used. Kilham feels that one of the most promising of these techniques is presented in an Air Force Contract AF19(604)-5706, by Austin King of the Industrial Components Div. of Raytheon. This technique utilizes a lithium-molybdenum salt solution and is said to offer the following advantages:

- Lower firing temperature
- Ability to metalize very small orifices
- Excellent manufacturing control (by virtue of being a solution)

Caution must be taken in the use of silver-containing brazing alloys in contact with ceramic members at high temperatures. Migration of silver along ceramic surfaces, under certain conditions, has lead to the formation of conducting films and growth of metallic whiskers on the ceramic surface. This situation may be corrected by using an alloy that doesn't contain silver.

Directly connected with high operating ambient temperature components is their ability to transfer heat. In addition to having to withstand these high temperatures, Kilham notes, various components such as magnetic components have an additional temperature rise. Consideration of how this heat energy is transferred becomes an important item. It is known that radiated heat varies as the fourth power of the absolute temperature and it is found that at 300°C and above, radiation is the dominant method of heat transfer. Figure 15 gives plots of radiation coefficient at various ambient temperatures up to 500°C.

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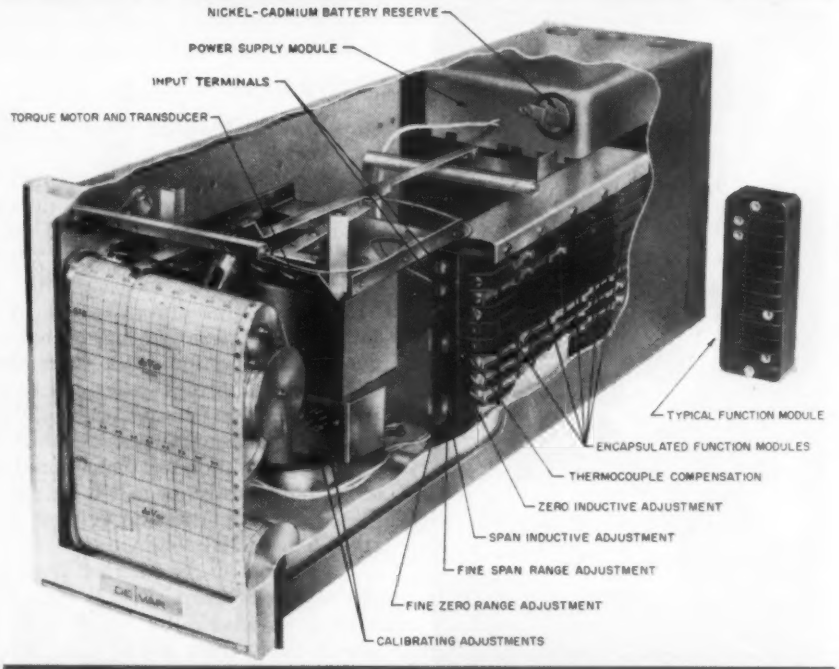

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COMPONENTS DIGEST

NEW INSULATIONS

Among the new products announced at the Third Annual National Conference on the Applications of Electrical Insulation, the following were of particular interest to electromechanical engineers.

High Temp. Magnet Wire

A significant advance in the field of film coated conductors is the development of Allex, a Class 220C film coated magnet wire. Thermal life, (30,000 hours at 240°C), measured by the AIEE #57 procedure, is said to far surpass that of existing film coated conductors. In addition to the thermal stability which places Allex wire well above a Class H rating, the wire possesses outstanding solvent resistance, exceptional retention of dimensional stability under pressures and the desirable electrical properties associated with other film coated conductors.

Developed by the Magnet Wire Div. of Essex Wire Corp., Fort Wayne, Ind., Allex is available in round wire, in sizes ranging from AWG 4 through 16 in single and heavy builds. Shaped wires in heavy builds are available in standard square sizes and on rectangular conductors up through 100,000 square mil cross section.

The excellent thermal stability of the polymer should make it possible to reduce the size and weight of motors, replacing bulky glass covered conductors which have been a stumbling block to smaller designs on many units. The chemical resistance, coupled with its low weight loss characteristics at elevated temperatures, should make it suitable for encapsulated windings of all types and for hermetically sealed electronic equipment. It has been established by tests conducted in the hand tool motor field that Allex wire, used with Class A insulating materials, will operate for considerably longer periods of time under overload conditions with no drop off in electrical properties.

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"Teflon TE-9500"

"Teflon TE-9500" FEP-fluorocarbon dispersion is a new experimental member of the family of Teflon fluorocarbon products developed by the Polychemicals Dept. of Dupont, Wilmington, Del. It combines the processing advantages of both a low fluid viscosity and a low melt viscosity together with well-known chemical, electrical, and mechanical properties. This union of dispersion, melt flow, and end-product is expected to lead to many uses as a surface coating and impregnant, particularly in the wire and cable field.

In looking over the Conference literature put out by the Polychemical Dept., we found, in their August issue of the Journal of Teflon, a very useful 2 page table of specifications pertinent to Teflon TFE resins or to items fabricated from these polymers. Specs include Mil, AMS & ARP, ASTM and NAS for fabricated shapes; film, tape and laminates; electrical insulation; hose; back-up rings; coatings; wire and cable.

For more information on Teflon TE-9500:
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For your copy of Teflon Specification Table:
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High Temp. Laminates

Four new industrial thermosetting laminated plastics, including a new high-temperature material, were exhibited by Synthane Corp., Oaks, Pa., at the conference. Synthane Grade AA-HT, the high-temperature laminate, has an asbestos woven fabric reinforcement and a modified phenolic resin binder. This laminate demonstrates high bonding strength, good machinability and good dimensional stability when exposed to moisture. It is recommended for continuous exposure up to 500°F. Tests indicate that this material retains 40% of its mechanical strength after exposure for 1,000 hours at 500°F. Synthane Grade FR-2, a flame-retardant plastic laminate, represents a new advance in this type of material. This material is a paper-base laminate with a flame-retardant phenolic resin binder. It has all of the outstanding electrical properties of paper-base Grade XXXP, but may be punched at room temperature and is self-extinguishing. Grade FR-4, a glass-fabric epoxy with flame-retardant properties, was developed specifically for printed circuit and general electronic component use. It has qualities similar to a general-purpose type of glass-base epoxy and to a high-temperature type of glass-epoxy. It has extremely high mechanical strength at room temperature, good dielectric loss and dielectric breakdown properties under both dry and humid conditions.

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Epoxy Glass Formed Wedges

Inmanco, Div. of Insulation Manufacturers Corp., Chicago, Ill., announced

NEW digitork STEP MOTOR BULLETINS

DATA SHEETS
APPLICATION NOTES

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- Positions ..... up to 12
- Action ..... detent, 30° indexing
- Contacts ..... break-before-make or make-before-break
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- Mounting ..... back of panel

For detailed information ask for Bulletin 22.

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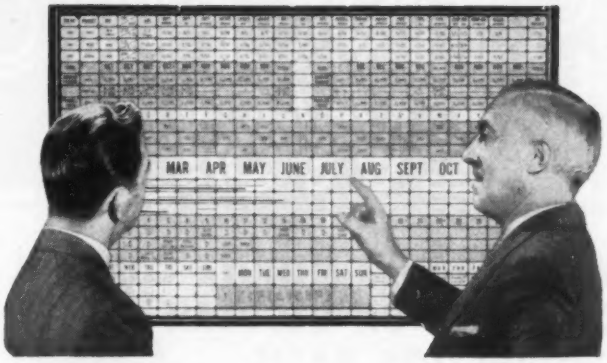

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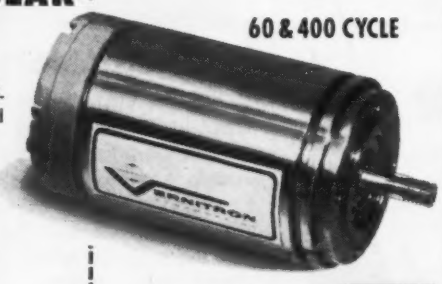

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COMPONENTS DIGEST

a new addition to a family of wedges — a Class F temperature wedge made from epoxy glass laminate, in the recognized shapes of curve-formed and square-formed. Two wall thicknesses, 0.020″ and 0.025″, in a range of standard sizes are available. The epoxy glass laminate's high dielectric properties are not lost in the conversion into wedge shapes. For example, the 0.20″ thick material shows a typical dielectric breakdown short time of 50 kv; step by step 54 kv. Selection of the correct shape and size assures tight wedging that will be permanent over a wide temp. range.

Write No. 522 in Box on Inquiry Card

Mica Coil Forms

Mykroy 1116, a special grade of glass-bonded mica which can be finished to 10-18 micro-inches for smooth potentiometer coil forms, is available from Electronic Mechanics, Inc., Clifton, N.J. The smooth finishes of the mica allow tiny 0.0003″ wires to be wound smoothly and evenly, so that a brush riding across the winding will not bump or chatter. Since the coefficient of thermal expansion of the glass-bonded mica is the same as that of stainless steel, the dimensions of the mandrel when subjected to high operating temperatures change equally with those of the wire. Mykroy 1116 withstands operating temperatures up to 1000°F and has excellent electrical characteristics.

Write No. 524 in Box on Inquiry Card

Insulating Tapes

Of the several items announced by Permacel, New Brunswick, N.J., three are of particular interest: A flat copper wire imbedded between polyester film so the wire is completely covered gives moisture resistance, toughness, high edge tear resistance and flexibility. Other materials such as silicones can be used as the imbedment material. EE 6100 hi-temp reflective tape is a lamination of aluminum foil and glass cloth with a pressure-sensitive silicone adhesive. It is used on missile launching cables as protection against the extremely high temperatures of blast flames on takeoff. EE 4716 polyester Mylar film cable wrapping tape is an

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CIRCLE NO. 69 ON INQUIRY CARD

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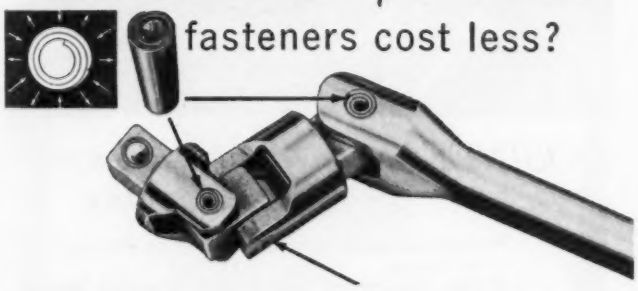

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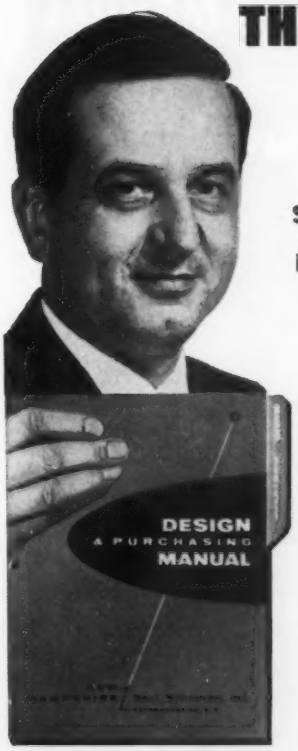

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COMPONENTS DIGEST

extremely thin tape with high dielectric strength, excellent insulation properties, low moisture-vapor permeability, high heat resistance and high elongation.

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Phenolic Laminate

Insurok T-777 is a paper-base, phenolic laminate with exceptional flame-retardant characteristics. Introduced by the Richardson Co., Melrose Park, Ill., it is immediately available copper-clad or non-clad. The company rates the material as self-extinguishing with zero inches burning distance.

Write No. 526 in Box on Inquiry Card

Silicone Varnish

A new Class H varnish that cures at 150 C in just six hours was announced by Dow Corning Corp., Midland, Michigan. Designated Dow Corning 981 Varnish, the new material is as easy to process as most Class A and Class B varnishes, thus eliminating the need for high-temperature curing ovens in producing Class H electrical equipment. It meets AIEE requirements for both 180C and 220C systems. Extensive tests indicate that despite the lower curing temperature — 50C below that required for most other silicone varnishes — the 981 varnish has greater heat stability than any other varnish known, according to the company. Run-off is also substantially lower than that for other varnishes, assuring appreciable savings in reduced waste, equipment maintenance and clean-up time.

Write No. 520 in Box on Inquiry Card

Paper-Nylon Laminate

For use as electrical insulation in hermetic applications, a laminate of 100% rag paper and nylon was developed by Rogers Corp., Rogers, Conn. The nylon film is extruded directly onto the paper in a molten state, eliminating the need for an adhesive and thereby reducing toluol extractibles. Test values for a sheet 0.010″ thick with a 0.005″ nylon film show a tensile strength of 144 psi in machine direction, electric strength of 1120 vpm, a film-paper adhesion of 2.25 lbs. per 3″ width, Elmendorf tear of 990 gm in machine direction and 1120 gm in cross machine direction. Also revealed by test data is the fact that the elongation of the nylon does not have sufficient time to make itself noticed under rapid loading, and advantage in high speed automatic wiring.

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An extensive variety of nameplates adhere permanently to any surface. Select from three types of pressure sensitive backing: heat or solvent applied; pressure applied; and water applied. Unrestricted choice of size, shape, and color and choice of 8 type faces are available. The nameplates meet the weather, salt-spray abrasion and temp. requirements of applicable mil specs. Full catalog available.

Source: Anodyne, Inc.
North Miami Beach, Fla.

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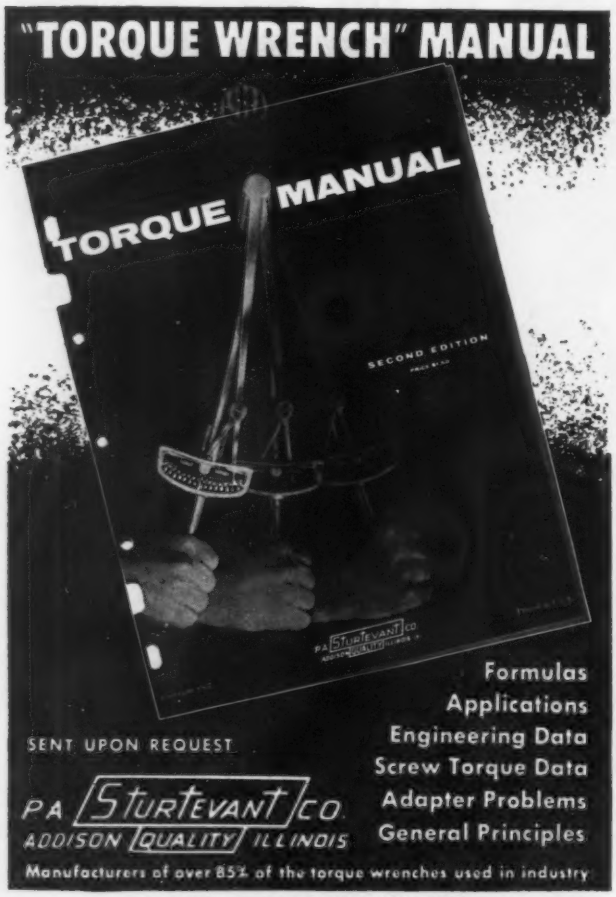

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New Components For Electromechanical Systems

Differential Amplifier

All-solid state differential operational amplifier contains neither tubes nor mechanical choppers; it is a true dc differential amplifier whose input is entirely "floating" and yet has a long term drift stability in the sub-millivolt region. Its typical input current is well under 0.1 millimicroamp, thus making possible its use in long time-constant integrating circuits using small polystyrene capacitors ($R = 10$ Mohm, $C = 0.1\mu f$ for a 1 sec integrator) or its use in electrometer type amplifier circuits. There is no limit on the size of a common mode signal save the dielectric strength of the insulating materials. Aside from the usual operations of addition, integration, differentiation, scaling, and inversion, its differential inputs make possible high impedance voltage following and amplification, direct subtraction, and precise current driving to grounded loads, as well as a host of mono-, bi-, un-, and conditionally stable applications. George A. Philbrock Researches, Inc., Boston, Mass.

Write No. 477 in Box on Inquiry Card

Rotary Switches

Capable of withstanding a 1,200-volt dielectric surge and designed for a 40,000 cycle minimum life, detent-action switches rotate 360 deg. in either direction, or can be set for any number of eight positions. Molded from a mineral glass alkyd material, units are said to have good heat resistance properties, dielectric strength and high resistance to arc, impact and shock. Standard Electrical Products Co., Dayton, Ohio.

Write No. 314 on Inquiry Card

Multi-Point Temp Control

Temperature controller provides accurate automatic two-position control for up to ten separate processes. Instrument can also be used as a single point controller, five-point three-position controller and manual-balance indicator. Any points not being used for control of a multiple-temperature process can monitor other processes. Accuracy: 0.5% of range. Thermo Electric Co., Inc., Saddle Brook, N. J.

Write No. 491 in Box on Inquiry Card

Tunnel Diode

Called the "Uni-Tunnel" diode, a semiconductor device combines high efficiency performance at low voltage levels with extreme temperature stability over a wide temperature range. The ability of the diode to operate efficiently at low voltage levels eliminates the complex circuitry previously required for low-level operations. The device utilizes the tunneling effect to provide high forward conductance at very low voltage levels, When biased in the reverse direction, the familiar tunnel diode current characteristic appears as a leakage current of micro-amp magnitude. Hoffman Electronics Corp., Los Angeles, Calif.

Write No. 682 in Box on Inquiry Card

Printed Circuit Modules

Providing maximum circuit board area in a given space, printed circuit modules are constructed of crossed boards interlocking to form a column. End plates may also be printed circuits and can carry tube sockets or transistors and plug-in connectors. The structure can be made in a wide variety of shapes and sizes including a sub-miniature version about ⅜ sq in. Arthur Ansley Manufacturing Co., New Hope, Pa.

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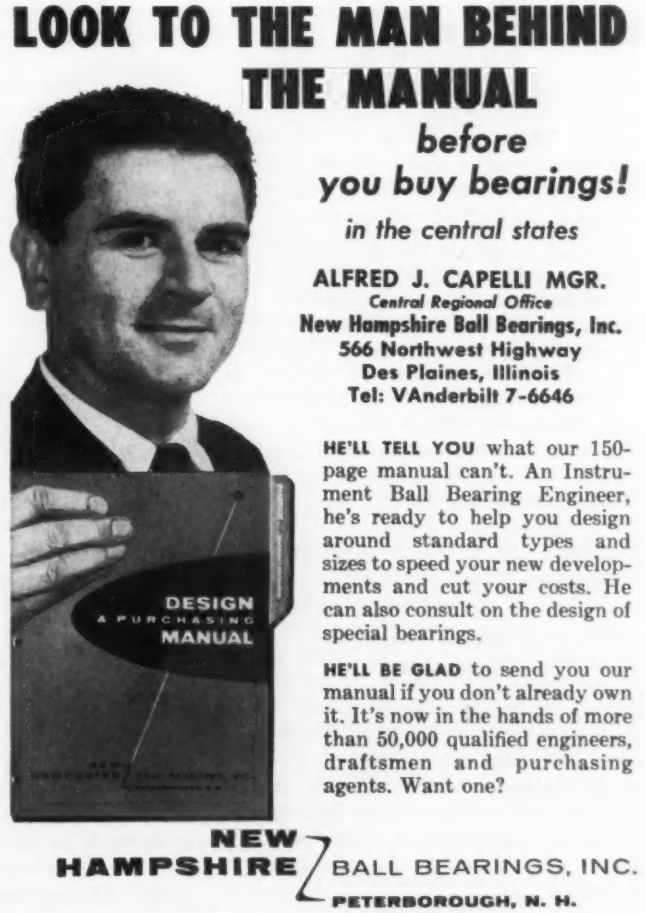
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NEW COMPONENTS

Frequency Standards

Transistorized, low-cost frequency standards provide outputs of 5 Mc, 1 Mc and 100 kc for use in frequency control systems. Precision-engineered unit offers stability of ± 5 parts in 10^{10} per day. An emergency battery source with automatic switch-over enables continuous operation during line failure. Manson Laboratories, Inc., Stamford, Conn.

Write No. 418 in Box on Inquiry Card

Oscilloscope

Operating with low-cost signal-amplifier and time-base plug-in units and basically an indicator, an oscilloscope contains a 5-inch crt with 3.5 kv accelerating potential, an 8 x 10 cm viewing area, an aplitude and sweep-time calibrator, and a regulated 30 watt dc power supply. The indicator accepts any two of four presently available plug-in units—which drive the crt deflection plates directly. Dimensions 13¾ in. high x 9¾ in wide x 21¾ in. deep. Weight: less than 27 lbs. Tektronix, Inc., Beaverton, Oregon.

Write No. 411 in Box on Inquiry Card

Resonant Reed Relay

New self-holding relays are said to reduce the cost of a system in two ways: They selectively provide positive contact without the use of auxiliary holding relays and other components required by typical remote control systems; and the broad bandwidth response allows use of increased drift characteristics in the transmitted frequencies, thereby reducing transmitter costs. Self-holding feature eliminates the vibrating, intermittent contact of conventional designs. P. R. Mallory and Co., Du Quoin, Ill.

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DC Power Supplies

Designed and tested to meet performance specs under the "worst possible combination of component characteristics," a power source supplies continuously variable dc voltages, (0 to 50 v range) from 105 to 125 v single-phase, 48 to 62 cycle ac input. Units with either 0.1% or 0.01% regulation are available. Max output current: 2, 5, 10 or 15 amps. A new mechanical design enables any component to be reached without unsoldering a single connection. Consolidated Avionics Corp., Westbury, N. Y.

Write No. 476 in Box on Inquiry Card

DC Amplifiers

Utilizing "driven shield" techniques to block out spurious signals, amplifiers attain common mode rejections of 120 db from dc to 1.5 kc and 140 db at 60 cps. Units amplify low-level transducer signals over the dc to 10 kc frequency range and serve as an all-purpose laboratory instrument. Output: 200 ma peak-to-peak and 20 volts peak-to-peak; recovery time: less than one second for 10 times full scale overload. Consolidated Electrodynamics Corp., Pasadena, Calif.

Write No. 326 in Box on Inquiry Card

Feed Thru Terminal

Miniature terminals secure directly to panel assemblies by means of an integrally molded threaded body. Flats, which form part of the integral mold, make it easy to insert the threads into an assembly with either an automatic or manual coupling drive. The tin-plated bras rod of the terminal conforms to QQ-B-626 and HP4-14 and has contoured soldered pot flats on each end which are precision oriented and burr free. They are designed for tie points, insulators and wire terminuses and many other applications. Whitso, Inc., Schiller Park, Ill.

Write No. 321 in Box on Inquiry Card

Self-Locking Synchro Clamps

Half turn of a screw locks and unlocks synchro clamps; integral stops enable settings to be felt. Therefore, they require only screwdriver access to release a component, resulting in smaller packaging of servo assemblies. Without loosening or failing, the clamps underwent 30 hrs of vibration at 5 to 2000 cps and up to 30 G's acceleration. Timber-Top, Inc., Freeport, L. I., N. Y.

Write No. 464 in Box on Inquiry Card

Synchronous Motors

Measuring only 0.960 inch in length, hysteresis synchronous motors provide constant speed drive for computers and navigational devices meeting MIL-E-5272, units pull-in torque is 0.025 oz. in. Kollsman Motor Corp., Dublin, Pa.

Write No. 311 in Box on Inquiry Card

Standoff Terminals

A midget standoff terminal features a turret stud with teflon body for "press-fit" installation. Overall length: 0.296″; the brass soldering lug measures 0.156″ long, the through-chassis teflon body is 0.148″ in dia, with a 0.172″ dia shoulder for chassis support. Sealectro Corp., Mamaroneck, N. Y.

Write No. 385 in Box on Inquiry Card

Terminal Block Connectors

Claimed to cut average wiring time 75%, screwless, lugless and positive locking, terminal block connectors enable wires to be connected or disconnected with only a ¼ turn of a screw driver. It requires no special tools or parts. These cam action block connectors may be used in most types of electronic and electrical equipment, including aircraft, automotive, marine, and military products, appliances, and lighting equipment. Camblock Corp., Natick, Mass.

Write No. 344 in Box on Inquiry Card

Low-Torque Potentiometers

Producing a torque of 0.003 oz-in. to 0.025 oz-in. and measuring 1 inch in dia by 1.31 inch in length, new precision potentiometers weigh only 0.6 ounce. They accurately divide an electric current or voltage in proportion to shaft rotation up to 354 Linear and sin-cos functions and useful angles in a toroid form up to 360 can be provided. Units withstand vibrations to 1000 cps at 10 g and meet Mil-E-5272, Procedure II, without altering output accuracy. Precious metal resistance elements ranging from 100 to 100,000 ohms hold noise to a minimum. Giannini Controls Corp., Duarte, Calif.

Write No. 420 in Box on Inquiry Card

Vane-Axial Blower

Designed to meet Mil-E-5272A environmental conditions, compact blowers deliver from 275 to 550 cfm at static pressures of 7.5 to 1.5 inches of water (standard density). They may be supplied with either 400-cps ac or dc motors. Developed specifically for aviation and electronic instruments and equipment, the cooling units weigh 7½ lbs and are 5.75″ long and 7.54″ in dia. Torrington Mfg. Co., Torrington, Conn.

Write No. 349 in Box on Inquiry Card

Centrifugal Blowers

Delivering 2000 cfm at 11″ H_2O, a 5 hp, 3′ high blower is designed for continuous duty. It operates from a 3 phase, 220 volt, 60 cycle source at a speed of 3450 rpm. Drawings and curves are available upon request. IMC Magnetics Corp., Maywood, Calif.

Write No. 458 in Box on Inquiry Card

Military Mesa

New mesa transistor is said to represent the first ultra-high-speed germanium switching transistor to be so classified by the military. Price: $11.00 in quantities of 100 or more. Motorola Semiconductor Prods. Inc., Phoenix, Ariz.

Write No. 468 in Box on Inquiry Card

For Your 3-Ring Binder

NEW DATA SHEETS

Most of these data sheets contain complete specs, mounting configurations and other important details associated with the application of the products described. For your free copy of the data sheets listed on this page, enter the appropriate number of the item on the Inquiry Card.

Magnetic Amplifiers 919

With thermocouple, strain gage, photocell or other low level inputs, 400 cps amplifiers can deliver 0 to ±5 volts output into a 50K load at accuracies of 0.1% in a single stage of amplification. Applications include linear amplification, null and error detection, summing with electrical isolation, integrating, microvolt and microampere measurement. Typical circuit configurations with associated quantitative problems illustrate amplifier's usefulness. Airpax Electronics Inc., Fort Lauderdale, Fla.

Precision Potentiometers 901

Resistance values for multi-turn potentiometers range from 5 to 200,000 ohms with standard linearity tolerances to 0.3%. For single-turn units, values range from 5 to 150,000 ohms with standard linearity tolerances to 0.2%. Sizes available vary from ½" to 3" dia. Six data sheets give applicable mil specs and environmental data. Lockheed Electronics Co., Los Angeles, Calif.

Variable Resistors 927

Six basic types and 60 models of linear motion variable resistors come in both wirewound and composition types which are covered with printed circuit and Teflon leads. Design of the contact arm, wiper carriage and constant torque adjustment screw result in an electrically stable, smooth, noise free unit capable of operating under severe requirements. Centralab, Milwaukee, Wis.

XY Plotters 946

Designed for plotting data from digital and analog computers and for plotting tracking data from missile-range instrumentation systems, transistorized XY plotting boards contain electroluminescent panels for glare free backlighting. These 30" x 30" units, with both single and dual arms, operate in any position, horizontal to vertical. Four hundred cp servo motors and amplifiers provide high accelerations and terminal velocities. Computer Systems, Inc., Monmouth Junction, N. J.

Parametric Diodes 920

Voltage variable capacitance and high Q of parametric diodes permit their efficient use as harmonic generators, reactance tuners, fractional milli-micro-second switches out of avalanche, modulators, demodulators and all other functions associated with the class of variable reactance devices. For parametric amplification, the potential difference across the diode varies from −4.5 volts to +0.4 volts to cause a 4-to-1 swing in capacitance without drawing an excess of 5 microamps. Other typical values include: cutoff frequency of at least 150 KMC; at S-band using a 2800 Mc signal, an 11,200 Mc pump, a gain of 17 db with a 1.3 db noise figure is standard. At X-band, using a 9800 Mc signal and a 19,600 Mc pump, a gain of 14 db with a 1.5 db noise figure is standard. Semiconductor Devices, Inc., Newport Beach, Calif.

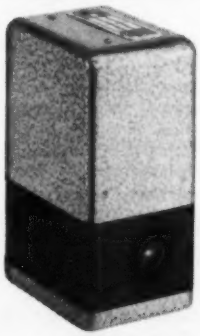
Miniature Servo-Accelerometer 929

Completely contained in a hermetically-sealed cylinder only 2" long and 1" in dia. are all the electronic, electrical and mechanical elements of a closed-loop force balance system. An output of 0.2 mA/g is delivered over a ±20 g range (special to ±100g's) with a linearity and null stability exceeding 0.001 g's. Kistler Instrument Corp., N. Tonawanda, N.Y.

Synchro Control Transformers 904

Four technical data sheets cover 17 synchro control transformers. Electrical performance characteristics, performance at temperature extremes, average mechanical characteristics and phasing are given in detail. John Oster Mfg. Co., Racine, Wis.

One eye sees...



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DATA SHEETS

Inductors 909

High-Q fixed inductors with extreme stability under temperatures from — 55 to 375C exhibit excellent inductance and Q over range of temperature up to 500C intermittent operation with good retrace characteristics. Unit is completely inorganic, employing one piece construction for reliability and compliance for Class C operation under MIL-C-15305-A. Nytronics, Inc., Berkeley Heights, N. J.

Electronic Ceramics 922

Miniature ceramic devices include memory cores beginning at 0.030 inch dia.; cup cores to specified inductance recording heads; poly-crystalline yttrium-iron garnets with minimum line widths and loss tangent; and high "Q" materials for use as inductors, tuning slugs and transformers with frequency ranges from 1 to 50 Mc. Lockheed Electronics Co., Los Angeles, Calif.

Printed Circuit Boards 921

Having parallel etched copper circuits terminating in connector fingers, boards eliminate initial tooling and art work costs, save board space and assembly labor, standardize board size, and provide an economical packaging methods for quantities up to 5,000 units. Made of a paper base epoxy, they suit standard or modified connectors. Elgin Laboratories, Inc., Waterford, Pa.

Microminiature Relays 902

Incorporating a configuration in which the terminals project from the side instead of the end, a relay is said to be the only one with this style to employ a rotary relay motor. The relay mounts on the side with greatest area which improves vibration and shock characteristics of circuit boards. Release time: 5 msec max. Pick-up time: 5 msec max at nominal coil voltage at 25°C. Shock: 150 G, 11 msec. Filtors, Inc., Port Washington, N. Y.

Silicon Diodes 903

New industrial and military medium power silicon diodes include: diffused junction silicon general purpose diodes; silicon double anode (twin Zener) diodes, and diffused junction silicon Zener diodes. Three data sheets show the diodes in round and hexagonal axial lead package configurations. Charts and curves illustrate operational characteristics. Controls Co. of America, Tempe, Ariz.

Fused Quartz 906

Precision fabricated, micro-fused quartz of optical quality is available from stock for service in critical infrared systems, microwave equipment and numerous other analytical applications. Special shapes, sizes and thicknesses can also be obtained with precision drilled "chip-free" holes and notches according to specs. The leaflet includes an easy-to-read table on the physical properties of clear fused quartz. Dell Optics Co., Ltd., West New York, N. J.

DC Power Supplies 945

Providing regulation of 0.1% or 10 mv, with virtually negligible ripple, transistorized power supplies have continuously variable current limiting, two panel meters for full-time (no switching) voltage and current monitoring, and calibrated main and vernier dc output controls. They may be remotely programmed. Three models are offered: 0 to 100 v at 100 ma, 0 to 36 v at 200 ma and 0 to 18 v at 1 amp. Electronic Measurements Co., Inc. Eatontown, N. J.

One-Half Inch Square Trimmer 944

Containing a lead screw adjustment which offers accurate calibration or trimming over 16200° or 45 turns, a tiny wirewound trimmer features rugged construction designed to withstand severe environmental conditions. The black anodized, precision machined housings stack ten to the cubic inch of space. Standard resistance range: from 50 ohms to 50 K ohms, with other values on special order. Resistance tolerance: ±5%. Technology Instrument Corp., Franklin Park, Ill.

Servo Development Kit 930

Consisting of a permanently packaged group of standardized servomechanism components, a servo kit enables the assembly of virtually an unlimited variety of mechanisms and gear trains. It enables the servo designer to prove-out tentative designs with a low inertia mechanism closely simulating the final production unit — and from parts available from his own stockroom. Precision Mechanisms Corp., East Meadow, N. Y.

DC Motor 910

Features of a 1" dia, battery operated type HYQM motor include: high efficiency; low current drain; square brushes with pigtail connections; and standard self-aligning sleeve or ball bearings. Specs: 4.5 to 30 v dc; 1,500 to 5,000 rpm (governed); 0 to 0.20 oz-in torque; clockwise or counterclockwise rotation; and ambient temperature to 200°F. Barber-Colman Co., Rockford, Ill.

Sub-FHP Gearmotor 912

With precision cut gears and oil impregnated bronze bearings, four pole, shaded pole motors designed for continuous duty, operate at low speed assuring quiet and long life. Units available in sizes, 1/30, 1/60 and 1/100 hp and in nine speeds from 1 to 200 rpm. Motors are approx. 6" long and 4" in dia and weigh between 4 and 6 lbs. Units are said to provide high torque at modest cost. Von Weise Gear Co., St. Louis, Mo.

Subminiature Relays 917

Designed to meet the most severe environmental requirements of present day prototype missiles, a new subminiature relay is said to incorporate a completely new rotary relay motor and a new header design. Insulation resistance: 10,000 M ohms min at 25°C; shock: 100g's at 11 msec; pick-up time: 10msec max 26-5 volts at 25°C; release time: 10 msec max. Filtors, Inc., Port Washington, N. Y.

Adhesives Selector Chart 926

Chart shows outstanding properties of key adhesives and hardeners . . . their tensile shear strengths at different temperatures and in several fuels. Also, the operating temperature range, izod impact, coefficient of thermal expansion and numerous other criteria are indicated. Hysol Corp., Olean, N. Y.

Metal Coated Ceramics 949

Permanent metal-to-ceramic bonding techniques extend the use of ceramics into fields where metal alloys were formerly required. In addition to design considerations, bulletin describes properties and applications of stealite and high alumina ceramics for low and high temp metal to ceramic seals. Centralab, Milwaukee, Wis.

Gold Alloy Preforms 947

Described are two uses for gold alloy preforms: as a joining material to produce an ohmic junction and as an alloy junction material when doped with N or P type elements. Data sheet gives melting points, typical alloys for various applications, sizes and tolerances. Accurate Specialties Co., Inc., Hackensack, N. J.

PNPN Applications 948

Covering a wide range of circuit functions, a series of papers discusses many new application areas for PNPN devices. Published biweekly, each paper analyzes a specific design problem and its solution with four-layer circuitry. Solid State Products, Inc., Salem, Mass.

Cylinder Actuators 905

Powerful pneumatic actuator precisely positions many types of mechanical processing equipment: variable speed drives, butterfly valves, control valves, proportioning pumps and electrical components such as rheostats, auto-transformers and potentiometers. A piston with lipseals assures friction-free stroking and an integral high-capacity positioner. The lightweight unit operates in any position. Conoflow Corp., Philadelphia, Pa.

Semiconductor Grade Germanium 915

Grades of semiconductor germanium include: germanium-dioxide, first reduction germanium metal, and intrinsic polycrystalline germanium. Bulletin also discusses services for reclamation of germanium from scrap such as crystal ends, broken slices, saw dust, acid etchants and ores. High Purity Metals, Inc., Hackensack, N. J.

High Voltage Pentodes 916

Beam-type pentodes' 20 ma plate current and 15 w plate dissipation make them ideal for use in medium voltage power supplies as the shunt regulator tube or in higher voltage power supplies as the series regulator tube. Their 5000 transconductance suggests their use in medium power, medium voltage amplifier circuits. They are for use with plate voltages up to 1 kv. Victoreen Instrument Co., Cleveland, Ohio.

WORTH FILING

Electronic Equipment

A 272-page book gives specs and prices on a wide variety of electronic parts and equipment for service, industrial, and audio applications. It is completely indexed by product and by manufacturer with 99 manufacturers represented. A special new products index consists of three categories: amateur and citizens' band gear; general products; stereo, hi-fi equipment. Another special feature of the catalog is its industrial tube cross reference.

Source: Lampley Electronic Supplies
Benton, Ill.

For Your Copy Write No. 807 in Box on Inquiry Card

Switching Transistors

"Transistor Guide for Switching Circuit Designers" guides engineers in selecting proper transistors for such applications as saturated DCTL, SCTL, RTL, RCTL, and DTL low-level logic circuits. Literature also discusses nonsaturated logic, for example, current switching, medium-level switching up to 400 ma, and high-level switching including dc to dc converters and static relays. Germanium and silicon switching transistors are correlated with their proper application. Besides showing designs and uses of inverters and flip-flops as basic building blocks for switching circuitry, catalog discusses transistor properties necessary to obtain optium performance of inverter and flip-flop in "transistor logic".

Source: Philco Corp., Lansdale Div.
Lansdale, Pa.

For Your Copy Write No. 820 in Box on Inquiry Card

WORTH BUYING

Noise Measurement

"Handbook of Noise Measurement" covers the measurement of noise and vibration, and describes equipment requirements, procedures and the interpretation of results. This 100-page book contains comprehensive surveys and the measurement of sound levels and sound-pressure levels. Four appendices include decibel conversion tables, vibration charts, definitions and extensive references. Price: $1.00.

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West Concord, Mass.

Shock and Vibration Measurement

All types of auxiliary equipment used between a shock or vibration pickup and the final indicator or recorder are covered in the new American Standard Method for Specifying the Characteristics of Auxiliary Equipment for Shock and Vibration Measurements. Special emphasis has been given to the following preamplifiers; linear and logarithmic amplifiers; frequency selective equipment which includes bandpass filters, waxe analyzers, octave-band analyzers, integrating circuits and differentiating circuits; and carrier systems. The standard comprises a part of a group of definitions, standards, and specifications used in acoustical work. Price $.0.80.

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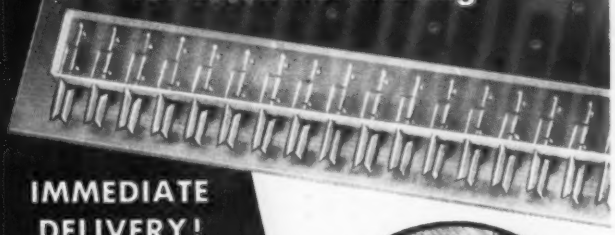

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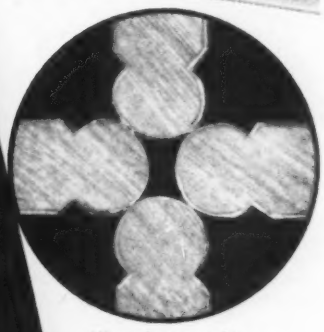

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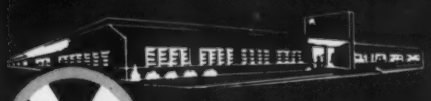

Methode manufacturing corp.

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CIRCLE NO. 82 ON INQUIRY CARD

For Your Literature File

NEW CATALOGS

Most of these catalogs contain complete specs, mounting configurations and other important details associated with the application of the products described. For your free copy of the catalogs listed on this page, enter the appropriate number of the item on the Inquiry Card.

Gas Driven Gyro 950

Two-degree-of-freedom displacement gyro, a hot-gas-driven instrument, provides accurate displacement reference for missiles during short-duration flights. In a "planned return to simplicitiy" hot-gas propellants proved a better means for accelerating the gyro rotor than either electrically-or-mechanically-actuated drives. Design characteristics given in catalog include: 14 major parts; reliability — 99.6%; shelf-life — minimum of 5 years; ambient temperature range: —65 to +165 F; acceleration — 30g for 30 sec; size — 4⅛" dia x 5¼" high; weight — 3½ lbs. (4 pp) Lear, Inc., Santa Monica, Calif.

Relay Color Coding Kits 962

Wall chart gives color coding information on 30 color-selective conversion kits for modifying relays. Seven color-location diagrams show how and where to use kits. Coil application data show how to select magnet coils for relays with any possible circuit arrangement. (8 pp) The Clark Controller Co., Cleveland, Ohio.

Air Control Valves 964

Mechanically and manually operated air valves utilize a valve segment which makes possible thousands of different valve styles constructed from less than fifty standardized parts. Catalog covers ¼" NPT, 2-position balanced spool valves, normally closed or normally open 3 way or 4 way styles. Three page spread presents all model numbers, specs and operators in easy-to-read chart. Types of operators include: knob and lever, clevis, roller cam, over-riding roller cam, foot pedal, treadle and air operators. Hoffman Valves, Inc., Dayton, Ohio.

Digital Building Blocks 968

First showing how basic test equipment modules can be used to rapidly check out a new digital system design, brochure then describes their replacement with printed circuit board electrical equivalents to produce a reliable, working prototype or final system. Circuit diagrams and photographs illustrate how basic as well as complex digital circuits can be readily implemented with the modules. Circuits considered are — basic shift register, binary counter, forward-backward counter, binary adder and binary multiplier. Harvey-Wells Electronics, Inc., Natick, Mass.

Video Amplifier Applications 982

An application note describes the design of high-quality video amplifier circuits using low-cost 2N741 mesa transistors. Included are circuit schematics, performance curves, and photographs of a completed 10-mc amplifier. Eleven drawings supplement text. (4 pp) Motorola Semiconductor Products Inc., Phoenix, Ariz.

Waterproof Wire Markers 975

Pressure sensitive cloth, available in any combination of letters, numbers and symbols eliminate checking and ringing out of complicated wiring systems. These adhesive backed markers, guaranteed to 350 F, tenaciously cling to surfaces providing a good alternative to metal and string tags or notching. (7 pp) North Shore Nameplate, Bayside, N. Y.

Servomotors 985

Of special interest in a catalog is a technical discussion of damping theory, which compares and evaluates the various means to achieve damping, including rate-feedback and velocity-damping. Development of pertinent transfer function equations is shown. Both the size 8 and size 11, standard units covered include: servometers; velocity-damp servometers; inertia-damp servomotors; and servomotor-generators with optional voltage requirements and mechanical characteristics. (24 pp) Helipot Div. Beckman Instrument, Inc., Fullerton, Calif.

"White Rooms" 654

A new service provides complete, pre-engineered "white rooms" in one package, including installations and employee training. Bulletin illustrates 31 different construction and operational details of a typical dust-controlled white room. (4 pp) Controlled Environment, Inc., Needham, Mass.

FHP AC Motors 959

Two, 4 and 6-pole shaded pole motors plus high-efficiency 6-pole permanent split capacitor units comprise a line of ac motors. Catalog gives speed, power and dimensions with ratings for 60 cycle, 115 v operation; motors can also be wound for 208 v or 230 v operation at 50 or 60 cycles. (4 pp) The Leece-Neville Co., Gainesville, Ga.

Panel Fasteners 657

Self-aligning, self-locking panel fasteners permit simple installation with hand or power tools. Used in a wide variety of removable panel applications, the self-contained fastener has no accessories to be lost or misplaced. (4 pp) Hi-Shear Corp., Torrance, Calif.

Adjustable Speed Drives 656

New half-wave, fhp, electronic speed drives employ silicon controlled rectifiers instead of tubes to supply power to the motor. Bulletin explains important design features such as a new control module with encapsulated circuitry which provides long life and protection against shock and vibration. (4 pp) General Electric Co., Schenectady, N. Y.

Power Supply Modules 960

Troubles that originate from faulty regulated dc power supplies include: stray and false information; false triggering of circuits, harmful changes in pulse shapes; distortion of in-put signals by ripple; and high transients which destroy transistors. Besides discussing these problems, a brochure also details achievements in latest miniature plug-in modules, and how they prevent malfunctions. (18 pp) Valor Instruments, Inc., Gardena, Calif.

Magnetic Disc Brakes 961

Catalog covers line of magnetic disc brakes including series with torques ranging from: 1 to 3 lb-ft for mounting on size 40 frame motors; 1½ 15 lb-ft for mounting on motor frames 55C, 66C, 182 and 184; 10 to 105 lb-ft for adaptation to 213C, 215C, 254UC, 284UC, 286UC motor frames; a series for special adaptation to older frame motors; and a series with torques from 125 to 575 lb-ft for NEMA frames 324U, through 405U. (8 pp) Stearns Electric Corp., Milwaukee, Wis.

Logic Trainer 980

Designed for training personnel in digital circuit operation, logic design bread-boarding, and digital circuit testing, a digital logic trainer effectively demonstrates basic cricuit operations, as well as the effect of loading and timing on circuit and network performance. A front panel contains fifty pre-wired digital circuits, with individual logic symbols clearly identifying input connections and their function. (4 pp) Epsco, Inc., Cambridge, Mass.

Analog Computer 994

Solution to multi-component phase equilibrium problems with analog computers are discussed. The multi-component system reviewed comprises one in which equilibrium temperature, pressure, L/V ratio, and liquid and vapor compositions are to be calculated, given the concentration of a specific component in either the liquid or vapor phase. The generalized method of solution can be used for any number of components. (7 pp) Computer Systems, Inc., Monmouth Junction, N. J.

Test Point Connectors 992

Designed for printed circuit applications, test point connectors can be located at convenient or critical positions for easy test takeoff points. Single contact and multiple contact types with 4, 6, 8, 28 and 42 test points are available for right angle dip soldering to printed circuit boards. Units accept and hold securely a nominal 0.080" dia test probe. Borchure also describes molding compounds such as mineral filled melamine, glass filled plaskon alkyd, glass filled diallyl phthalate and Orlon filled diallyl phthalate. (6 pp) Continental Connector Corp., Woodside, N. Y.

Sub-Miniature Capacitors 978

Complete line of variable capacitors are described. One typical unit is Type "T" that has a Q greater than 3000 at 1 Mc, a high torque-to-mass ratio and a temperature coefficient less than 60 ppm deg C. Unit meets Mil-C-92A. Catalog also covers tube sockets, connectors, insulators, inductors and knobs and dials. (20 pp) E. F. Johnson Co., Waseca, Minn.

NEW CATALOGS

Measurement Instruments 971

Precision instruments for measurement of temperature, pressure, level and flow are described: pressure potentiometers; low pressure measurement system; electronic micromanometer; temperature transducers for surface, liquid, and gas temperature measuring systems; temperature standards; liquid detection systems; and mass flow systems. Application information included. (8 pp) Trans-Sonics, Inc., Lexington, Mass.

Instrument Servos 652

Including a comprehensive table of specs arranged to facilitate selection, a brochure deals with vacuum tube and solid state servo indicators and repeaters for measurement, control data conversion and computation. Types described include 3" and 2" dia millivolt-meters, ratiometers, shaft position repeaters and analog-to-digital converters. (4 pp) North Atlantic Industries, Inc., Plainview, N. Y.

Angular Accelerometer 955

Nine series of linear and angular accelerometers available in excitation frequencies from 400 to 10,000 cps and acceleration ranges from 1 to 700G are illustrated and described. (4 pp) Schaevitz Engineering, Pennsauken, N. J.

Glass-Metal Components 999

Described are: precision glass and glass-metal components, sapphire-to-glass seals, infrared sensing and reference levels. Vacuum measuring instruments for the pressure range from atmospheric to 10^{-10}mm Hg are also covered. (12 pp) The Fredericks Co., Bethayres, Pa.

Servo Components 998

Catalog lists surplus synchros, ac and dc motors, servo motors, inverters, actuators, geared motors, generators, and other components. Also included are curves of servo motors, circuit diagrams, and schematics. (30 pp) Servo-Tex Products Co., Hawthorne, N. J.

Vacuum Diffusion Pumps 997

Basic information on diffusion and booster pumps includes speed curves for small, medium and large models ranging from 1 to 32-inch sizes, and includes both tabular specs and outline drawings for each pump. Theory of diffusion pumps and their operation at very low pressures serve as reference when designing vacuum systems or checking their performance. (12 pp) NRC Equipment Corp., Newton, Mass.

Spectrophotometer Accessories 956

Accessories described enable spectrophotometers to render such analyses as flame photometry, fluorometry, reflectometry, spectroradiometry, colorimetry, solid phase studies, reaction rate studies, and turbidity observations. (13 pp) Beckman Instruments Div., Fullerton, Calif.

. . . We've really hit the jackpot with the new DIEHL Vacuum Tube Servo Amplifier. For response, linearity and power output, this new servo amplifier just can't be beat. Here are five reasons why:

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SPECIFICATIONS

Cat. No.	VA075-300
Output	75 Watts, Nominal
Gain	1000 volts/volt in power amplifier with max. feedback. Feedback can be reduced with potentiometer provided, with resulting increase in gain.
Input Imp.	500,000 ohms
Phase Shift	a) Less than 10° phase lag of envelope at one third carrier frequency. b) Less than 2° at carrier frequency.
Noise	100 MV., Max., Input Shorted
Power Req.	Diehl VP3-100 high voltage power supply, or equivalent.

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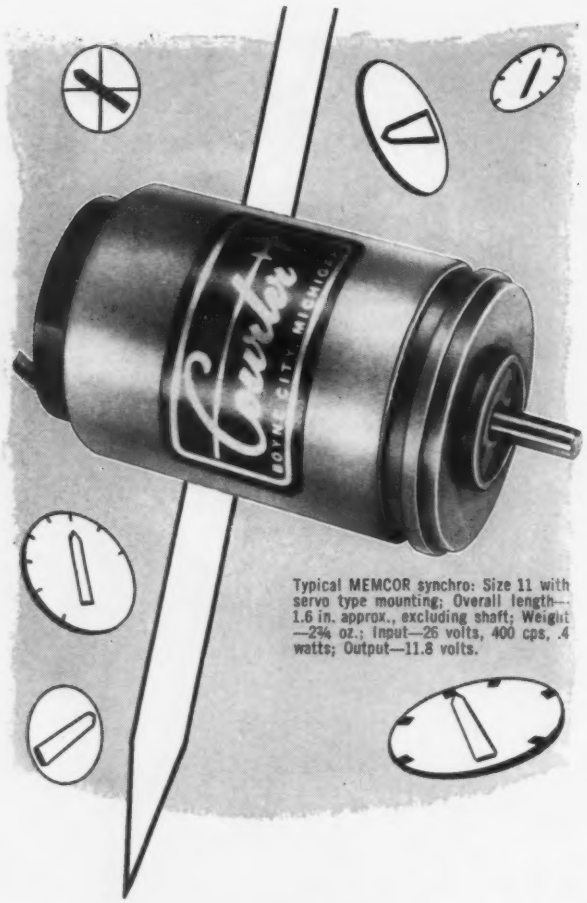
Typical MEMCOR synchro: Size 11 with servo type mounting; Overall length—1.6 in. approx., excluding shaft; Weight—2¾ oz.; Input—26 volts, 400 cps, .4 watts; Output—11.8 volts.

Memcor Synchros and Synchro Indicator Packages

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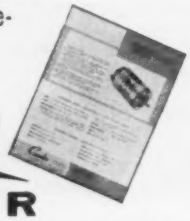

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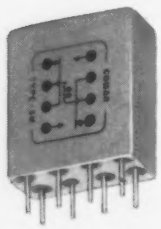

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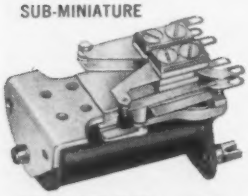
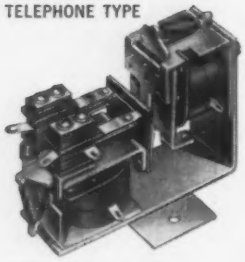


TELEPHONE TYPE



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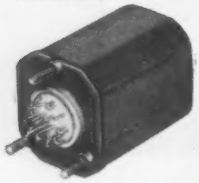

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